WATER RESOURCES DEVELOPMENT PROJECT

# POINT JUDITH

RHODE ISLAND

# DESIGN MEMORANDUM NO. 1

## HYDROLOGY AND HYDRAULICS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

JULY 1965

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
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ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.
NEDED-R

1 July 1965

SUBJECT: Water Resources Development Project, Point Judith, Rhode Island, Design Memorandum No. 1, Hydrology and Hydraulics

TO: Chief of Engineers
ATTN: ENGCW-E

There is submitted herewith for review and approval Design Memorandum No. 1, Hydrology and Hydraulics for the Water Resources Development Project, Point Judith, Rhode Island in accordance with EM 1110-2-1150.

FOR THE DIVISION ENGINEER:

1 Incl
as (5 cys)

JOHN WM. LESLIE
Chief, Engineering Division

WATER RESOURCES DEVELOPMENT PROJECT

POINT JUDITH
RHODE ISLAND

DESIGN MEMORANDUM NO. 1

## DESIGN MEMORANDA INDEX

| No. | Title | Submission Date | Approved |
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| 1 | Hydrology and Hydraulics | 1 July 1965 | |
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| 3 | Concrete Materials | | |
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WATER RESOURCES DEVELOPMENT PROJECT

POINT JUDITH
RHODE ISLAND

DESIGN MEMORANDUM NO. 1

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POINT JUDITH
RHODE ISLAND

## DESIGN MEMORANDUM NO. 1

## HYDROLOGY AND HYDRAULICS

## INTRODUCTION

### 1. PURPOSE

This memorandum describes the hydrologic and hydraulic criteria applicable to the design of structures included in the Point Judith Water Resources Development Project. Part I - Hydrology, includes sections on climatology, rainfall and design runoff. Part II - Tidal Hydraulics, presents data on experienced tidal flood heights, the determination of design tidal flood levels and associated wave heights, wave runup and overtopping.

### 2. DESCRIPTION

The Point Judith area of the towns of South Kingstown and Narragansett is on the Rhode Island coast about 40 miles south of Providence. There are 3 miles of barrier beaches between the low headlands of Point Judith on the east and Matunuck Point on the west. Behind the barrier beaches are three large interconnected tidal ponds, Point Judith, Potter and Upper Ponds with a combined shoreline of about 16 miles, extending north about 4 miles to the village of Wakefield in the town of South Kingstown. The Federal breakwaters that form the Harbor of Refuge inclose the eastern half of the ocean shore and the Breachway, a stabilized inlet for navigation to and from the ponds. Plate 1-1 shows the location and general plan of the project.

## PART I - HYDROLOGY

### 3. DRAINAGE AREAS

The drainage area of the Saugatuckett River is rectangular in shape, approximately 6 miles long, 3 miles wide and contains 16.7 square miles. The river originates in the swampy area of North Kingstown, Rhode Island and flows in a southerly direction for about $6\frac{1}{2}$ miles to Silver Spring Cove of Upper Pond. Approximately 5 percent of the area is residential, 30 percent in swamps with many mill dams and reservoirs, and about 65 percent forested which amply regulates the flow into Upper Pond.

The local drainage area begins at Upper Pond and encompasses 9.7 square miles bordering the ponds, and runoff flows directly into Upper, Point Judith and Potter Ponds. Most of the area is composed of flat brushland, swamps, forests and scattered ponds and is not considered to be effective in contributing to rapid runoff.

The three interconnecting ponds, namely, Potter, Point Judith and Upper, cover areas of 560, 2,250 and 280 acres, respectively, at elevation 10 feet above mean sea level.

## CLIMATOLOGY

### 4. CLIMATE

The Point Judith area has a temperate humid climate marked by four distinct seasons which are characteristic of its latitude and of New England. The area is in the zone of interaction of tropical and Arctic air masses resulting in changeable weather varying from hot and cold, and dry and wet. Owing to the moderating influence of the nearby Atlantic Ocean, and particularly to the variable easterly movement of high and low pressure systems across the area, extremes of either hot or cold weather are usually of short duration. In the winter, coastal storms frequently bring rainfall in contrast to snow in the more northerly areas of New England. In the summer, cooling relief from hot, humid weather is provided by easterly and southerly sea breezes, thunderstorms from the west, and cool air from the north. Prevailing winds are northwesterly in winter and southwesterly in summer. High winds, heavy rainfall and abnormally high tides may occur during any month of the year. Hurricanes and tropical storms occur during the months of August, September and October.

5. CLIMATOLOGICAL RECORDS

Since 1889 a U. S. Weather Bureau station has been maintained at Kingston, Rhode Island approximately 8 miles north of Point Judith. The records are considered to be representative of the climate at Point Judith.

6. TEMPERATURE AND PRECIPITATION

The average annual temperature at Point Judith, based on Kingston records, is 48° F. The coldest months, January and February, have mean temperatures of 28° F; and the warmest month, July, has a mean temperature of 69° F. The lowest temperature was -23° F. on 11 January 1942, and the highest 99° F. on 9 August 1949.

Annual precipitation has ranged from a minimum of 32 inches in 1943 to a maximum of 72 inches in 1898. Average annual precipitation is 48 inches, distributed rather uniformly throughout the year. Average monthly precipitation varies between 3.2 inches in June and July and 4.5 inches in March. Extremes of monthly precipitation have ranged from 0.04 inch in June 1949 to 13.56 inches in August 1952.

Monthly temperature and precipitation records are summarized in Table 1-1. Snowfall occurs from November to April, averaging 33 inches per year.

## RAINFALL AND RUNOFF

7. HURRICANE RAINFALL

The greatest recent rainfalls recorded were for the dissipating hurricanes, Connie and Diane, in August 1955. During 11-15 August, hurricane Connie caused rainfall varying from about 4 to 6 inches over southern New England and ended a period of drought. A few days later during 17-20 August hurricane Diane produced rainfall from 16 to 20 inches over Massachusetts. Although Point Judith did not receive excessive rainfall in either of these storms, hurricane Diane did cause a record fall of 13.1 inches in 55 hours (4.1 inches in 6 hours) at West Mansfield, Massachusetts 42 miles northeast of the

TABLE 1-1

MONTHLY TEMPERATURE AND PRECIPITATION
KINGSTON, RHODE ISLAND
(Elevation 100 feet msl)

| Month | Temperature in Degrees F. Mean | Maximum | Minimum | Precipitation in Inches Mean | Maximum | Minimum |
|---|---|---|---|---|---|---|
| January | 28.0 | 63 | -23(2) | 4.50 | 11.43 | 0.83 |
| February | 28.0 | 64 | -22 | 3.99 | 9.44 | 0.67 |
| March | 35.7 | 82 | - 4 | 4.51 | 9.67 | 0.23 |
| April | 45.0 | 85 | 8 | 4.35 | 9.70 | 0.72 |
| May | 55.1 | 93 | 25 | 3.81 | 8.95 | 0.67 |
| June | 63.9 | 96 | 30 | 3.20 | 7.42 | 0.04(4) |
| July | 69.4 | 98 | 38 | 3.20 | 11.75 | 0.43 |
| August | 68.1 | 99(1) | 33 | 4.43 | 13.56(3) | 0.79 |
| September | 62.0 | 95 | 25 | 3.73 | 12.66 | 0.35 |
| October | 52.1 | 87 | 13 | 3.83 | 12.05 | 0.27 |
| November | 41.5 | 76 | 4 | 4.42 | 10.25 | 0.41 |
| December | 31.0 | 65 | -17 | 4.36 | 11.59 | 0.83 |
| ANNUAL | 48.3 | 99(1) | -23(2) | 48.33 | 72.22(5) | 31.76(6) |

(1) 9 Aug 1949
(2) 11 Jan 1942
(3) 1952
(4) 1949
(5) 1898
(6) 1943

Point Judith area. On 16-17 September 1932, a tropical storm produced over 12 inches of rain in less than 24 hours at Westerly, Rhode Island. Many other areas in central Rhode Island received over 8 inches of rain in about 18 hours. Table 1-2 shows rainfall amount at a number of coastal southern New England locations.

TABLE 1-2

EXCESSIVE RAINFALL ASSOCIATED WITH HURRICANES OR TROPICAL STORMS FOR COASTAL SOUTHERN NEW ENGLAND LOCATIONS

| Location | Accumulated Rainfall in Inches 3-Hour | 6-Hour | 12-Hour | 24-Hour | Storm Total | Total Hours |
|---|---|---|---|---|---|---|
| 5-7 October 1962 (Hurricane Daisy) | | | | | | |
| Kingston, R. I. | - | - | - | 2.2 | 5.4 | - |
| Providence W. B. Airport | 1.7 | 2.6 | 4.8 | 6.6 | 9.5 | 57 |
| 20-21 September 1961 (Hurricane Esther) | | | | | | |
| Kingston, R. I. | - | - | - | 6.5 | 7.1 | - |
| Block Island, R. I. | 3.0 | 4.2 | 6.0 | 7.3 | 7.3 | 24 |
| Providence W. B. Airport | 1.4 | 2.3 | 3.7 | 4.9 | 4.9 | 24 |
| 11-12 September 1960 (Hurricane Donna) | | | | | | |
| New Haven, Conn. | 2.9 | 4.0 | 4.9 | 5.3 | 5.3 | 24 |
| 24 October 1959 | | | | | | |
| New Haven, Conn. | 3.0 | 3.1 | 3.2 | 3.3 | - | 15 |
| 16 October 1955 | | | | | | |
| Kingston, R. I. | - | - | - | 3.1 | 4.5 | - |
| Block Island, R. I. | 3.0 | 4.2 | 6.2 | 6.3 | 6.8 | 30 |

TABLE 1-2 (cont.)

| Location | 3-Hour | 6-Hour | 12-Hour | 24-Hour | Storm Total | Total Hours |
|---|---|---|---|---|---|---|
| | Accumulated Rainfall in Inches | | | | | |
| **18-19 August 1955 (Hurricane Diane)** | | | | | | |
| Kingston, R. I. | - | - | - | 2.2 | 3.1 | - |
| Providence, R. I. | 2.7 | 2.9 | 3.1 | 5.5 | 6.1 | 39 |
| New Haven, Conn. | 1.5 | 2.4 | 2.8 | 3.2 | 4.2 | 33 |
| **12 August 1955 (Hurricane Connie)** | | | | | | |
| Kingston, R. I. | - | - | - | 5.3 | 5.7 | - |
| Block Island, R. I. | 1.4 | 2.4 | 2.7 | 3.4 | 3.7 | 29 |
| New Haven, Conn. | 0.9 | 1.2 | 1.6 | 3.2 | 3.5 | 26 |
| **11 September 1954 (Hurricane Edna)** | | | | | | |
| Kingston, R. I. | - | - | - | 5.5 | 5.5 | - |
| New Bedford, Mass. | 1.4 | 2.8 | 3.3 | 3.5 | 3.4 | 15 |
| Woonsocket, R. I. | 3.2 | 4.8 | 5.8 | 6.3 | 6.3 | 15 |
| Providence, R. I. | 2.3 | 3.3 | 3.9 | 4.4 | 4.4 | 15 |
| New Haven, Conn. | 2.5 | 3.5 | 4.4 | 5.5 | 5.5 | 15 |
| **30-31 August 1954 (Hurricane Carol)** | | | | | | |
| Kingston, R. I. | - | - | - | 2.9 | 2.9 | - |
| New Bedford, Mass. | 1.1 | 1.3 | 1.9 | 1.9 | 1.9 | 13 |
| Providence, R. I. | 1.6 | 1.9 | 2.7 | 2.8 | 2.8 | 13 |
| Woonsocket, R. I. | 2.4 | 3.2 | 3.9 | 4.0 | 4.0 | 13 |
| **12-15 September 1944 (Hurricane)** | | | | | | |
| Kingston, R. I. | - | - | - | 2.4 | 4.4 | - |
| Providence, R. I. | 3.6 | 4.7 | 4.7 | 5.6 | 8.4 | 52 |
| New Bedford, Mass. | 1.5 | 1.8 | 1.9 | 2.1 | 3.4 | 52 |
| New Haven, Conn. | 3.1 | 3.9 | 4.0 | 4.0 | 8.5 | 54 |
| Portsmouth, R. I. | - | 1.3 | 1.4 | 2.7 | 4.3 | 40 |

TABLE 1-2 (cont.)

| Location | 3-Hour | 6-Hour | 12-Hour | 24-Hour | Storm Total | Total Hours |
|---|---|---|---|---|---|---|
| | Accumulated Rainfall in Inches | | | | | |
| **15-21 September 1938 (Hurricane)** | | | | | | |
| Kingston, R. I. | - | - | - | 1.3 | 2.8 | - |
| New Bedford, Mass. | 0.4 | 0.5 | 0.9 | 1.1 | 2.2 | - |
| Providence, R. I. | 0.5 | 0.6 | 1.0 | 1.1 | 3.1 | 73 |
| Nantucket, Mass. | 2.4 | 3.8 | 4.0 | 4.0 | - | - |
| New Haven, Conn. | 2.6 | 2.7 | 3.3 | 6.4 | 11.1 | 73 |
| **16-17 September 1933 (Hurricane)** | | | | | | |
| Kingston, R. I. | - | - | - | 2.7 | 6.0 | - |
| Block Island, R. I. | 1.1 | 1.8 | 2.6 | 3.7 | 6.4 | 70 |
| Providence, R. I. | 1.1 | 1.5 | 1.9 | 2.1 | - | 70 |
| Boston, Mass. | 2.2 | 3.5 | 5.0 | 5.6 | 7.8 | 40 |
| **16-17 September 1932 (Tropical Storm)** | | | | | | |
| Westerly, R. I. | - | - | - | 12.1 | 12.1* | - |
| Scituate Dam, R. I. | - | - | - | 11.4+ | 11.9* | - |
| Kingston, R. I. | - | - | - | 6.2+ | 8.3* | - |
| Providence, R. I. | 3.0 | 4.1 | 5.3 | 6.2 | 6.2 | 18 |
| Block Island, R. I. | 1.7 | 2.6 | 3.3 | 4.3 | 4.3 | 18 |
| **3 September 1928** | | | | | | |
| Kingston, R. I. | - | - | - | 3.0 | 3.0 | - |
| Block Island, R. I. | 3.1 | 3.3 | 4.1 | 4.1 | 4.1 | - |
| **12-14 July 1897** | | | | | | |
| New Haven, Conn. | - | 3.0 | 5.3 | 5.9 | 8.6 | 60 |
| Bridgeport, Conn. | - | 4.4 | 7.3 | 8.1 | - | 60 |

* No recorder station reported more than 24 hours of rainfall for this storm

The total rainfall associated with recent hurricanes that have caused tidal flooding in Point Judith area are 2.3 inches in September 1938, 4.0 inches in September 1944 and 3.0 inches in August 1954 (hurricane Carol).

The watershed surrounding the Point Judith ponds and the Saugatuckett River is very sluggish in producing high discharges. There are no streamflow records for the Saugatuckett River. The nearest gaged drainage area with topographic features comparable to that of the Saugatuckett River is the Wading River. Gaging stations on the Wading River are located at West Mansfield and Norton, Massachusetts approximately 40 miles north of Point Judith, with drainage areas of 19.2 and 42.4 square miles. The gaging station at West Mansfield has only been in operation since October 1953 while the Norton gage has been in use since June 1925. The Wading River at Norton, Massachusetts was used as a guide in determining the 10-year peak inflow in cfs per square mile. The topography of both areas is low and flat with numerous lakes, swamps and forests which are conducive to low runoff and relatively long periods of concentration.

The total storm rainfall of 13.05 inches experienced at Mansfield, Massachusetts during hurricane Diane in August 1955, resulted in a flow of 1,170 cfs (27.6 cfs per square mile) and 519 cfs (27.0 cfs per square mile) in the Wading River at Norton and West Mansfield, respectively; whereas in a number of other New England river basins, flows of over 500 cfs per square mile were caused by nearly similar rainfalls during this same storm. Hurricane Diane caused no tidal flood surge in the Point Judith area.

The discharges in the Wading River at Norton from rainfall antecedent and coincident with recent hurricanes which caused tidal flooding in the Point Judith area are listed below:

| Hurricane | Coincident Discharge cfs | Coincident Discharge cfs/sq.mi. |
|---|---|---|
| September 1938 | 180 | 4.25 |
| September 1944 | 137 | 3.25 |
| August 1954 (Carol) | 27 | 0.64 |
| September 1960 (Donna) | 26 | 0.61 |
| 10-Year Peak Discharge | 690 | 16.3 |

## 8. EFFECT OF RAINFALL ON POND LEVELS

For design purposes a rainfall and watershed peak discharge frequency of a 10-year return period was used concurrent with a peak hurricane induced tide inside the Point Judith ponds. Total runoff for different time periods was 1.15 inches for 15 minutes, 2.9 inches for 3 hours and 3.5 inches for 6 hours. Based on Wading River records at Norton, maximum discharge from the 25 square miles of land watershed above the Point Judith ponds was considered to average 400 cfs for the entire tide period. The direct inflow from rainfall on the 5 square miles of pond areas varied from 14,800 cfs during the 15 minutes of maximum rainfall, assumed to be concurrent with the maximum pond level, to under 500 cfs at the beginning of the hurricane tide. Rainfall on the pond areas was much more significant in affecting the pond levels than the rainfall on the land watershed.

The combined fresh water and salt water inflows through the breachway was routed into the ponds to determine the maximum pond elevation (see paragraph 22). The routing was then repeated using the salt water inflow only and the difference indicated that the fresh water inflow raised the pond level by approximately 0.4 foot over that of the salt water inflow alone.

# PART II - TIDAL HYDRAULICS

## NORMAL CONDITIONS

## 9. NORMAL TIDES

Two high and two low tides occur each lunar day in the Point Judith area. At Matunuck and in the Point Judith Harbor of Refuge the mean tide range is 3.1 feet, with mean low water 1.45 feet below mean sea level and mean high water 1.65 feet above mean sea level. Spring tides have an average range of 3.9 feet and a maximum range of about 6 feet. A maximum spring tide will reach an elevation 4.6 feet above mean low water (1.5 feet above mean high water). The time interval for a complete tidal cycle averages about 12 hours and 25 minutes.

At Galilee and Jerusalem, within Point Judith Pond just north of "The Breachway," and in the Upper Pond the mean tide ranges are 3.0

and 2.9 feet, respectively. In Potter Pond the mean tide range is 1.0 foot, while in the Potter Pond channel at the highway bridge the mean tide range is about 1.5 feet. Maximum tidal currents are less than 1 knot in the entrances to the Harbor of Refuge between the breakwaters, but average 2.9 knots on the flood and 2.7 knots on the ebb through the entrance to Point Judith Pond at "The Breachway." Tidal data for the Point Judith area are summarized in Table 1-3.

Tidal predictions are given for 19 locations in the Narragansett Bay area in the yearly publication of the U. S. Department of Commerce, Coast & Geodetic Survey, entitled "Tide Tables, East Coast, North and South America."

10. RECORDING TIDE GAGES

Data on the 12 recording tide gages in the Narragansett Bay area are given in Table 1-4. Six of these gages are presently in operation and six have recently been removed as indicated in the table. The locations of these gages are shown on Plate 1-2. Gage identification numbers, as indicated on this plate, correspond to the item numbers in Table 1-4.

11. FACTORS INFLUENCING TIDES

Tides are subject to meteorological influences such as changes in atmospheric pressure and strong winds, besides the normal gravitational effects of the sun and moon. A drop in barometric pressure of 1 inch of mercury will cause about a 1 foot rise in water levels. During coastal storms tide levels often build up several feet above the predicted elevations.

## EXPERIENCED HURRICANE AND SEVERE STORM TIDAL FLOODING

12. RECENT HURRICANES AND SEVERE STORMS

In the last 26 years the Rhode Island coast has been subjected to 3 major hurricanes, severe tidal flooding from the hurricane of 21 September 1938, from hurricane Carol on 31 August 1954 and moderate flooding from the hurricane of 14 September 1944. The 1938 and 1954 hurricanes followed paths 60 and 30 miles, respectively, west of Point Judith, thereby placing the Point Judith area in the sector of the

TABLE 1-3

NORMAL TIDES - POINT JUDITH AREA
SOUTH KINGSTOWN AND NARRAGANSETT, RHODE ISLAND

| | Matunuck, So. Kingstown | Sand Hill Cove, Narragansett | Galilee and Jerusalem, Pt. Judith Pond Narragansett | Potter Pond, So. Kingstown | Point Judith Upper Pond So. Kingstown |
|---|---|---|---|---|---|
| Mean Tide Range (feet) | 3.1 | 3.1 | 3.0 | 1.0 | 2.9 |
| Mean High Water (feet above msl) | 1.65 | 1.65 | 1.55 | 0.50 | 1.45 |
| Mean Low Water (feet below msl) | 1.45 | 1.45 | 1.45* | 0.50* | 1.45* |
| Average Spring Tide Range (feet) | 3.9 | 3.9 | 3.7* | 1.3* | 3.6* |
| Mean Spring High Water (ft. above msl) | 2.3 | 2.3 | 2.2 | 1.1 | 2.1 |
| Predicted Maximum Spring High Water (feet above msl) | 3.15 | 3.15 | 3.05 | 2.0 | 2.95 |
| Minimum Low Water (feet below msl) | 4.0* | 4.0* | 4.0* | - | 3.5* |

* Estimated

TABLE 1-4

TIDE GAGE INVENTORY DATA - NARRAGANSETT BAY AREA

| No. | Location | Type* | Period of Record | Agency |
|---|---|---|---|---|
| 1 | Block Island, R. I. | A,B,C | 16 Nov 1955 - To Date | NED |
| 1A | Narragansett, R. I. | A,B,C | 4 Oct 1956 - To Date | NED |
| 2 | Newport, R. I. | A,B,C | 10 Oct 1955 - 28 Apr 1965 | NED |
| 3 | Little Compton, R. I. | A,B,C | 27 Sept 1956 - 29 Sept 1964 | NED |
| 4 | Narragansett, R. I. | A,B,C | 10 Oct 1955 - 21 Apr 1965 | NED |
| 5 | Newport, R. I. | A,B | 10 Sept 1930 - To Date | USC&GS |
| 6 | North Kingstown, R. I. (Quonset Point) | A,B,C | 17 Dec 1956 - To Date | NED |
| 7 | Portsmouth, R. I. | A,B,C | 24 Oct 1955 - 24 Nov 1964 | NED |
| 8 | Somerset, Mass. | A,B,C | 24 Aug 1956 - 27 Apr 1965 | NED |
| 9 | Cranston, R. I. | A,B,C | 11 Oct 1955 - 30 Sept 1964 | NED |
| 10 | Providence, R. I. (State Pier No. 1) | A,B | 3 June 1938 - 23 June 1947<br>Aug 1956 - To Date | USC&GS |
| 11 | Providence, R. I. (Narragansett Electric Co.) | A,B | 1956 - To Date | Narragansett Electric Co. |

* Type of Gage: A - Recorder; B - Staff Gage; C - Maximum Level Gage

strongest and most damaging hurricane winds and where the storm surge was the highest. The center of the 1944 hurricane passed directly over the Point Judith area. The tracks of selected major hurricanes are shown on Plate 1-3. Minor tidal flooding has also occurred from a number of other hurricanes and severe storms in the past 26 years. Detailed descriptions of the three major hurricanes of recent years are given in the following paragraphs.

13. HURRICANE OF 21 SEPTEMBER 1938

The damage caused by tidal flooding from this hurricane was the highest ever experienced along the Rhode Island coast. An important factor in determining the height of flooding from a tidal surge is the stage of the normal tide at the time the hurricane surge arrives at the coast. The peak of the hurricane tide arrived in the Point Judith area about 1 hour and 15 minutes before the predicted normal high tide. Observed and predicted tidal heights in the Point Judith area during this hurricane are shown in Table 1-5. The increase in the hurricane flood levels in Point Judith Pond from the entrance at Galilee and Jerusalem at "The Breachway" to the north end of the pond illustrates the effect of wind setup. Hurricane flood levels in Point Judith Pond are shown on Plate 1-4. Hurricane tide curves at Matunuck, Sand Hill Cove and the entrance to the Breachway, Point Judith Harbor of Refuge are shown on Plates 1-5, 1-6 and 1-7. The location map and hurricane flood levels based on observed high water marks from the Connecticut-Rhode Island state line to Point Judith, Rhode Island are shown on Plates 1-8 and 1-9. During the September 1938 hurricane the U. S. Coast Guard reported waves 20 to 30 feet high in the Point Judith area.

The maximum wind velocity in New England during this hurricane was a recorded gust of 186 miles per hour at the Blue Hill Observatory in Milton, Massachusetts, 60 miles north of Point Judith, which is the maximum gust recorded in any New England hurricane. A sustained 5-minute wind of 121 miles per hour was recorded at the Blue Hill station. At other locations in southern New England, sustained 5-minute velocities ranged from 38 to 87 miles per hour. At Block Island, Rhode Island the wind attained a maximum recorded 5-minute sustained velocity of 82 miles per hour from the southeast and maximum gusts of 91 miles per hour before the anemometer was blown down. A maximum 5-minute wind velocity of 87 miles per hour from the southwest and gusts estimated at 125 miles per hour occurred at Providence, Rhode Island. The maximum gust and maximum 1-minute sustained wind velocity at Point Judith were estimated at 100 and 90 miles per hour,

TABLE 1-5

HURRICANE OF 21 SEPTEMBER 1938
TIDAL FLOOD DATA - POINT JUDITH AREA
SOUTH KINGSTOWN AND NARRAGANSETT, RHODE ISLAND

| Location | Tidal Flood Crest EST Time (P.M.) | Tidal Flood Crest Elevation (feet,msl) | Predicted Tide Elevation (feet,msl) | Max. Surge Above Predicted Tide (feet) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 4:30 | 12.3 | 2.0 | 10.3 |
| Potter Pond | 4:30 | 11.8 | 1.0 | 10.8 |
| Snug Harbor | 4:30* | 9.8* | 1.9 | 7.9 |
| North End, Point Judith Pond | 4:30* | 11.3* | 1.9 | 9.4 |
| Pt. Judith Upper Pond | 4:30* | 11.1* | 1.8 | 9.3 |
| Narragansett | | | | |
| Sand Hill Cove | 4:30 | 10.5 | 2.0 | 8.5 |
| Galilee and Jerusalem, Point Judith Pond | 4:30 | 9.5 | 1.9 | 7.6 |

| Location | Predicted Normal Tide: Low Tide EST Time (A.M.) | Low Tide Elevation (feet,msl) | High Tide EST Time (P.M.) | High Tide Elevation (feet,msl) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 11:15 | -1.75 | 5:42 | 2.35 |
| Potter Pond | 11:15* | -0.80 | 5:42* | 1.2 |
| Snug Harbor | 11:15* | -1.75 | 5:42* | 2.25 |
| North End, Point Judith Pond | 11:15* | -1.75 | 5:42* | 2.25 |
| Pt. Judith Upper Pond | 11:15* | -1.75 | 5:42* | 2.15 |
| Narragansett | | | | |
| Sand Hill Cove | 11:15 | -1.75 | 5:42 | 2.35 |
| Galilee and Jerusalem, Point Judith Pond | 11:15* | -1.75 | 5:42* | 2.25 |

* Estimated

respectively. The lowest barometric pressure ever recorded in New England was 28.04 inches at Hartford, Connecticut during this hurricane. Hartford is located about 65 miles northwest of Point Judith. Minimum barometric pressures of 28.66 and 28.90 inches, respectively, were recorded at Block Island and Providence. The forward speed of the hurricane near the Point Judith area was about 55 knots (63 miles per hour).

14. HURRICANE OF 14 SEPTEMBER 1944

The peak of the hurricane tide arrived at the Point Judith area about 2 hours and 15 minutes before the predicted normal low tide and therefore caused only a moderately high stage. Observed and predicted tidal heights in the area during this hurricane are shown in Table 1-6.

Wind velocities in the Narragansett Bay area during this hurricane were somewhat less than in the hurricane of 21 September 1938. At Block Island a maximum 1-minute sustained wind velocity of 88 miles per hour from the southeast was recorded and maximum gusts in excess of 100 miles per hour were experienced. At the T. F. Green Airport, Hillsgrove, Rhode Island the maximum 1-minute sustained wind velocity was 49 miles per hour from the southeast and the maximum gust was 90 miles per hour. Minimum barometric pressures of 28.34 and 28.51 inches were recorded at Block Island and Providence. The minimum recorded barometric pressure was 28.31 inches at Point Judith. The forward speed of the hurricane near the Point Judith area was about 30 knots (34 miles per hour).

15. HURRICANE CAROL, 31 AUGUST 1954

This was one of the greatest hurricanes in recent years and was exceeded only by the September 1938 hurricane. The peak of the hurricane tide occurred at the Point Judith area about one-half hour after the predicted normal high tide. Observed and predicted tidal heights in the area during this hurricane are shown in Table 1-7. The increase in the hurricane flood levels in Point Judith Pond from the entrance at Galilee and Jerusalem at "The Breachway" to the north end of the pond illustrates the effect of wind setup. Hurricane flood levels in Point Judith Pond are shown on Plate 1-4. Hurricane tide curves at Matunuck, Sand Hill Cove and the entrance to the Breachway, Point Judith Harbor of Refuge are shown on Plates 1-5, 1-6 and 1-7. The location map and hurricane flood levels based on observed high water marks from the Connecticut-Rhode Island state line to Point Judith,

TABLE 1-6

HURRICANE OF 14 SEPTEMBER 1944
TIDAL FLOOD DATA - POINT JUDITH AREA
SOUTH KINGSTOWN AND NARRAGANSETT, RHODE ISLAND

| Location | Tidal Flood Crest: EST Time* (P.M.) | Tidal Flood Crest: Elevation** (feet,msl) | Predicted Tide Elevation (feet,msl) | Max. Surge Above Predicted Tide (feet) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 10:15 | 8.3 | -0.3 | 8.6 |
| Potter Pond | 10:15 | 6.4 | 0.0 | 6.4 |
| Snug Harbor | 10:15 | 6.2 | -0.3 | 6.5 |
| North End, Point Judith Pond | 10:15 | 6.7 | -0.3 | 7.0 |
| Pt. Judith Upper Pond | 10:15 | 6.6 | -0.4 | 7.0 |
| Narragansett | | | | |
| Sand Hill Cove | 10:15 | 6.5 | -0.3 | 6.8 |
| Galilee and Jerusalem, Point Judith Pond | 10:15 | 6.1 | -0.3 | 6.4 |

| Location | Predicted Normal Tide: High Tide: EST Time (P.M.) | High Tide: Elevation (feet,msl) | Low Tide: EST Time (A.M.) (15 Sept) | Low Tide: Elevation (feet,msl) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 5:56 | 1.85 | 12:33 | -1.15 |
| Potter Pond | 5:56* | 1.2 | 12:33* | -0.2 |
| Snug Harbor | 5:56* | 1.75 | 12:33* | -1.15 |
| North End, Point Judith Pond | 5:56* | 1.75 | 12:33* | -1.15 |
| Pt. Judith Upper Pond | 5:56* | 1.65 | 12:33* | -1.15 |
| Narragansett | | | | |
| Sand Hill Cove | 5:56 | 1.85 | 12:33 | -1.15 |
| Galilee and Jerusalem, Point Judith Pond | 5:56* | 1.75 | 12:33* | -1.15 |

* Estimated

** Based on tidal elevation data for Newport, Rhode Island, stage related to Point Judith area, Rhode Island

TABLE 1-7

HURRICANE CAROL, 31 AUGUST 1954
TIDAL FLOOD DATA - POINT JUDITH AREA
SOUTH KINGSTOWN AND NARRAGANSETT, RHODE ISLAND

| Location | Tidal Flood Crest EST Time (A.M.) | Tidal Flood Crest Elevation (feet,msl) | Predicted Tide Elevation (feet,msl) | Max. Surge Above Predicted Tide (feet) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 10:00 | 11.9 | 2.1 | 9.8 |
| Potter Pond | 10:00 | 11.4 | 1.0 | 10.4 |
| Snug Harbor | 10:00* | 9.4 | 2.0 | 7.4 |
| North End, Point Judith Pond | 10:00* | 10.9 | 2.0 | 8.9 |
| Pt. Judith Upper Pond | 10:00* | 10.7 | 1.9 | 8.8 |
| Narragansett | | | | |
| Sand Hill Cove | 10:00 | 10.1 | 2.1 | 8.0 |
| Galilee and Jerusalem, Point Judith Pond | 10:00 | 9.1 | 2.0 | 7.1 |

| Location | Predicted Normal Tide: High Tide EST Time (A.M.) | High Tide Elevation (feet,msl) | Low Tide EST Time (P.M.) | Low Tide Elevation (feet,msl) |
|---|---|---|---|---|
| South Kingstown | | | | |
| Matunuck | 9:27 | 2.15 | 3:08 | -1.25 |
| Potter Pond | 9:27* | 1.0 | 3:08* | -0.3 |
| Snug Harbor | 9:27* | 2.05 | 3:08* | -1.25 |
| North End, Point Judith Pond | 9:27* | 2.05 | 3:08* | -1.25 |
| Pt. Judith Upper Pond | 9:27* | 1.95 | 3:08* | -1.25 |
| Narragansett | | | | |
| Sand Hill Cove | 9:27 | 2.15 | 3:08 | -1.25 |
| Galilee and Jerusalem, Point Judith Pond | 9:27* | 2.05 | 3:08* | -1.25 |

*Estimated

Rhode Island are shown on Plates 1-8 and 1-9. During the 31 August 1954 hurricane, an oceanographer of the Narragansett Marine Laboratory of the University of Rhode Island made wave observations at Saunderstown, Rhode Island, 10 miles north of Point Judith. He noted 20-foot high waves with lengths of 400 feet and periods of 11 seconds several hours after the occurrence of peak water height and wind velocity.

The wind attained a maximum 1-minute sustained velocity of 98 miles per hour from the southeast, with a maximum gust of 135 miles per hour at Block Island. A maximum 1-minute sustained wind velocity of 90 miles per hour from the east-southeast, with a maximum gust of 105 miles per hour, occurred at the T. F. Green Airport, Hillsgrove, Rhode Island. A minimum barometric pressure of 28.50 inches was recorded at Block Island and 28.79 inches at Providence. The forward speed of the hurricane near the Point Judith area was about 40 knots (46 miles per hour).

16. FREQUENCY OF TIDAL FLOODING

Although hurricane tidal flooding has been recorded since 1635 in the Narragansett Bay area, records of elevations are meager until recent years. Chronological lists of both hurricanes and severe storms that caused tidal flooding or high tides along the Rhode Island coast through the year 1960 are given in Tables A-1 and A-2 of Appendix A, Water Resources Development, Interim Report, Point Judith, Rhode Island, 24 January 1962. Since 1960 there have been 2 hurricanes and 6 significant storms along the Rhode Island coast. The two hurricanes, Esther - 21 September 1961 and Daisy - 6-7 October 1962, caused only minor tidal flooding along the New England coast. The storm of 30 November 1963 was a fast moving southwester with heavy wave action and winds gusting up to 90 miles per hour, causing moderate tidal flooding along the Rhode Island coast. The other 5 storms caused only minor tidal flooding along the New England coast.

In the preparation of a tidal elevation-frequency curve for the Point Judith area, consideration was given to similar data prepared for Newport Harbor, Rhode Island. The U. S. Coast & Geodetic Survey has maintained a recording tide gage at Newport Harbor from September 1930 to the present time, and there is good high water mark elevation data for the 1938 and 1954 hurricanes in this area. However, tidal variations at Newport Harbor, located in Narragansett Bay, are not always indicative of the tides at Point Judith which is exposed to the Atlantic Ocean. High water mark elevation data indicates that the still water tidal flood elevations for the 1938 and 1954 hurricanes at Point Judith (Matunuck) were 1.5 and 2.1 feet higher, respectively, than the corresponding elevations at Newport Harbor.

The maximum still water tidal elevation which might be expected on an average of once a year at Point Judith (Matunuck) is about 1.7 feet higher than the corresponding elevation at Newport Harbor. These relatively higher tidal elevations at Point Judith (Matunuck) have generally been confirmed by the Beach Erosion Board model studies of February 1958 as due to wave setup. Also use was made of the records of the Corps of Engineers, New England Division, recording tide gage located at Galilee, Point Judith Pond. The period of record of this gage is from October 1956 to date. The tidal elevation-frequency curve for Point Judith (Matunuck) is based on (a) observed tidal flood elevations for the 1938 and 1954 hurricanes; (b) Beach Erosion Board model test data of February 1958; and (c) Newport Harbor and Point Judith Pond (Galilee) tidal elevation data stage related to Point Judith (Matunuck).

The tidal elevation-frequency curve for Point Judith (Sand Hill Cove) is based on (a) observed tidal flood elevations for the 1938 and 1954 hurricanes; and (b) Newport Harbor and Point Judith Pond (Galilee) tidal elevation data stage related to Point Judith (Sand Hill Cove). Sand Hill Cove is located within the Point Judith Harbor of Refuge. The tidal elevation-frequency curve for Point Judith Pond (Galilee and Jerusalem) is based on (a) observed tidal flood elevations for the 1938 and 1954 hurricanes; (b) records of the tide gage at Galilee; and (c) Newport Harbor data stage related to Point Judith Pond.

The tidal elevation-frequency curves for Matunuck, Sand Hill Cove and Galilee and Jerusalem are shown on Plates 1-10, 1-11 and 1-12, respectively. These represent composite curves based on the 329-year period, 1635-1963, and the 149-year period, 1815-1963, that influence the upper portion of the curves and the 33-year period, 1931-1963, for which there is a continuous tide gage record that determines the lower portion of the curves. The calculated plotting positions of the points for the tidal elevation-frequency curves were determined from the following formula.

$$P = \frac{100(M-0.5)}{Y} \quad \text{where}$$

P = percent chance of occurrence in any 1 year
M = number of the event
Y = number of years of record

## DESIGN HURRICANE TIDAL FLOOD

### 17. STANDARD PROJECT HURRICANE

The Standard Project Hurricane (SPH) is representative of the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. The basis for the SPH is a transposition of the September 1944 hurricane. This storm, when located off Cape Hatteras, had the greatest energy of any known hurricane along the Atlantic coast.

In deriving the standard project hurricane, the 1944 storm was transposed so that it would be entirely over water from the Cape Hatteras area to the New England coast. This change in the track of the storm resulted in less rise in barometric pressure of the center of the storm as it moved northward than was actually experienced in 1944. The transposed hurricane was assumed to advance in a due northerly direction at a forward speed of 40 knots with its center crossing the New England coast at a point 49 nautical miles west of the entrance to Narragansett Bay.

The U. S. Weather Bureau provided a series of wind fields for the transposed hurricane from a position off Cape Hatteras until it dissipated over land. The Texas A & M Research Foundation, in connection with research work conducted by them for the Coastal Engineering Research Center, computed that the transposed hurricane would cause a tidal surge of 11.2 feet at Newport, Rhode Island. The observed 1938 hurricane surge was 8.2 feet. The ratio of these surges (11.2/8.4) gives a response factor of 1.33.

The standard project tidal flood surge was obtained by multiplying the observed 1938 hurricane surge by the response factor 1.33. The resulting surge was then added to the appropriate mean spring high water elevation to obtain the tidal flood elevation. This computation is summarized below for Matunuck and Sand Hill Cove.

| | Matunuck (feet) | Sand Hill Cove (feet) |
|---|---|---|
| Observed 1938 Hurricane Tidal Level, msl (Stillwater) | 12.3 | 10.5 |
| Predicted Tidal Stage, msl | 2.0 | 2.0 |
| Observed 1938 Hurricane Surge | 10.3 | 8.5 |
| Standard Project Surge | 13.7 | 11.3 |
| Mean Spring High Water, msl | 2.3 | 2.3 |
| Standard Project Flood Elevation, msl (Stillwater) | 16.0 | 13.6 |

## 18. DESIGN HURRICANE TIDAL FLOOD LEVEL

The cost of plans to provide protection against flood levels accompanying the standard project hurricane exceeded the estimated recurring flood damages. Therefore all plans of protection to these extreme and rare levels were dropped from further consideration. Studies of protective works, using the stillwater level of the flood of record (21 September 1938) as a basis of design, showed that economical structures could be provided to prevent about 90 percent of the estimated recurring damages of the 1938 hurricane in the Point Judith Pond area. The selected design stillwater elevations of 12.5 and 10.5 feet msl outside and inside the Harbor of Refuge, respectively, represent the maximum levels reached by hurricane floodwaters in a 326-year period. At the Breachway where wave setup is smaller, the design stillwater level is 9.5 feet msl.

## 19. DESIGN WAVE HEIGHTS

Design wave heights at Point Judith were based on wave studies made by the Department of Civil Engineering of the Massachusetts Institute of Technology under a contract with the U. S. Army Engineer Division, New England to investigate certain aspects of the design of a hurricane barrier for the east passage of Narragansett Bay, Rhode Island. One of the objectives of the investigation was to determine the size of wind generated waves to be expected to strike the barrier and to select the design wave. Details of this study are presented in Hydrodynamics Laboratory Report No. 66, February 1964, Massachusetts Institute of Technology, titled "Study of Hurricane Barrier for Lower Narragansett Bay."

After investigating both the wave-spectrum method and the significant-wave method of predicting wave heights, it was decided that due to the extensive data on which the significant-wave formulae are based, including some data for high wind velocities, that the significant-wave method would give satisfactory results. The computations of significant wave heights and periods were carried out on an IBM 1620 digital computer using the wind fields of the transposed September 1944 hurricane approaching the Rhode Island coast with a 40-knot forward speed. Plate 1-13 shows the wind field located to produce maximum winds in the Point Judith area.

The design wave heights at Point Judith are based on a significant wave height of 26 feet and a period of 12 seconds. Wave heights at the toe of the protective works have been calculated on the premise that the maximum height that can be sustained is 0.78 times the depth of water at the toe. These heights varied from 0 to 14.4 feet along the exposed coast at Matunuck-Jerusalem and also within the Harbor of Refuge at Galilee-Sand Hill Cove. Wave heights would, theoretically, become zero on the berm of the structure when the berm elevation is at design stillwater level. Most of the wave energy would be dissipated on the beach slopes, but there would be some uprush of water on the berm.

Wave heights in the entrance channel at the Breachway where the control structure is located are estimated at 8 feet. The wave energy that would be carried through the 150-foot opening would be dissipated rapidly by diffraction and refraction in the relatively broad and shallow areas of Point Judith Pond.

Wave heights within the pond would be about 2 feet in the Galilee-Jerusalem area immediately behind the protective works and would regenerate to about 4 feet in the northern portion near Wakefield. These heights represent a reduction of 5 feet at the southern portion and no change at the northern end as a direct result of hurricane protection improvements.

## 20. MAXIMUM WAVE RUNUP AND TOP ELEVATION OF STRUCTURES

Runup values were calculated for numerous locations on the protective structure by the method outlined in "Wave Runup on Composite

Slopes" by Thorndike Saville, Jr., Coastal Engineering Research Center, Washington, D. C. using wave heights ranging up to the significant wave height of the design storm. Different combinations of composite and simple slopes and berm widths were designed to prevent overtopping of the protective structure. It was assumed that the runup on rock slopes would be reduced 50 percent because of the roughness factor.

Water transport by waves running through the 150-foot wide navigation opening would have negligible effect in raising the water level within Point Judith Pond.

The selected hurricane protection plan and sections shown on Plates 1-14 and 1-15 for the Point Judith area consist of composite slopes and concrete walls with top elevations varying from 13.0 to 22.0 feet msl. The breachway control structure is shown on Plate 1-16. The maximum wave runup and top elevation of structures are shown in Table 1-8.

## MODIFIED FLOOD LEVELS

### 21. GENERAL

Water levels within Point Judith, Potter and Upper Ponds will be kept below damage levels for all hurricanes of record by narrowing the breachway opening to the 150-foot width of the authorized channel with concrete abutments and rock dikes. The protective structures along the beaches would prevent all storm induced flow over the beaches into the ponds. The waterway area of the Breachway was designed by tidal flood routing computations to give the required reduction in hurricane tidal flood levels within the ponds and to insure that under normal conditions there would be only a slight increase in the currents in the opening and no noticeable change in the tidal range. The hurricane protection improvements in the plan would provide protection along the exposed coast and shore of the ponds against the design storm level, equivalent to that of the 1938 flood of record. Flow through the Breachway control structure and fresh water inflow from rainfall runoff would combine to produce modified tidal flood levels behind the protection during hurricane tidal floods. An analysis was made of each of these factors to determine their combined effect on hurricane tidal flood levels.

TABLE 1-8

MAXIMUM WAVE RUNUP AND TOP ELEVATION OF STRUCTURE

| Location | Elevation: Top (feet,msl) | Elevation: Ground at Toe (Ave.) (feet,msl) | Wave Height at Toe (Max.)* (feet) | Maximum Runup: Height (feet) | Maximum Runup: Elevation (feet,msl) |
|---|---|---|---|---|---|
| Matunuck Beach | | | | | |
| Station 0+00 to 3+25 | 16.0 to 20.0 | 10.0 | 2.0 | 2.5 | 15.0** |
| Station 3+25 to 31+00 | 20.0 | 0.0 | 9.8 | 6.5 | 19.0** |
| Station 31+00 to 43+00 | 20.0 | 0.0 | 9.8 | 6.8 | 19.3** |
| Station 43+00 to 50+00 | 20.0 | -0.3 | 10.0 | 6.7 | 19.2** |
| East Matunuck State Beach | | | | | |
| Station 50+00 to 100+00 | 17.5 | -6.0 | 14.4 | 4.4 | 16.9** |
| Beachway Control Structure | | | | | |
| Station 102+70 to 104+75 | 16.0 | +6.0 | 5.1 | 3.2 | 15.7** |
| Station 107+60 to 112+65 | 16.0 | +7.0 | 2.7 | 3.3 | 13.8*** |
| Galilee | | | | | |
| Station 113+25 to 115+20 | 16.0 | +6.0 | 3.6 | 3.3 | 13.8*** |
| Station 124+00 to 139+00 | 22.0 | +0.3 | 8.2 | 11.4 | 21.9*** |
| Sand Hill Cove State Beach and Sand Hill Cove | | | | | |
| Station 139+00 to 157+00 | 17.0 | -2.0 | 6.8 | 4.5 | 15.0*** |
| Station 157+00 to 172+50 | 14.0 | -4.6 | 9.0 | 2.8 | 13.3*** |
| Station 172+50 to 178+25 | 14.0 to 13.0 | +8.0 | 2.0 | 1.5 | 12.0*** |

* Based on breaking wave height, $H_B = 0.78d$, where d = water depth at toe of structure
** Based on design stillwater level 12.5 feet msl
*** Based on design stillwater level 10.5 feet msl

## 22. EFFECT OF BREACHWAY CONTROL STRUCTURE

After the construction of the barriers and dikes the main access of tidal floodwaters to the Point Judith and Potter Pond areas will be through the Breachway control structure. The amount of inflow through the Breachway is dependent largely on the height and duration of the hurricane tide. While the August 1954 hurricane tide was slightly lower than the 1938 hurricane tide, its longer duration would permit more water to flow through the Breachway and thus raise the ponds to a higher elevation. The 1954 hurricane tide was therefore used in the evaluation of the effectiveness of the Breachway control structure. The effect that the recommended system of protection would have had on the 1938 and 1954 hurricane tidal floods in this area is given in Tables 1-9 and 1-10. Tide curves for the hurricanes of 1938 and 1954 at the entrance to the Breachway, Point Judith Harbor of Refuge, are shown on Plate 1-7. The hurricane tide at the entrance to the Breachway was routed through the opening using the following formula.

$Q = CA\sqrt{2gH}$ in which

$Q$ = flow in cfs

$C$ = coefficient of discharge

$A$ = area of waterway opening in square feet

$g$ = acceleration of gravity = 32.2 feet/second$^2$

$H$ = head causing flow through the opening in feet

The coefficient C was estimated to be 0.7 based on the results of tests summarized in an unpublished report of the Waterways Experiment Station, Vicksburg, Mississippi.

The flood levels in Point Judith Pond for hurricane Carol, 31 August 1954, are shown on Plate 1-4. Natural flood levels and flood levels modified by the flow through the Breachway control structure and the fresh water runoff are both shown on this plate. The natural flood level profile is based on high water mark elevation data. The effect of wind setup in Point Judith Pond is illustrated on the profiles by the increase in flood levels from the entrance to the pond at the Breachway to the north end of the pond.

TABLE 1-9

EFFECT OF WATER RESOURCES DEVELOPMENT PROJECT ON HURRICANE FLOOD LEVELS - POINT JUDITH AREA HURRICANE OF 21 SEPTEMBER 1938

| Locality | Flood Levels Without Barriers (feet,msl) | Flood Levels With Barriers (feet,msl) | Reduction (feet) |
|---|---|---|---|
| South Kingstown | | | |
| Matunuck | 12.3 | 6.0 | 6.3 |
| Potter Pond | 11.8 | 6.0 | 5.8 |
| Snug Harbor | 9.8 | 6.0 | 3.8 |
| North End, Point Judith Pond | 11.3 | 7.5 | 3.8 |
| Pt. Judith Upper Pond | 11.1 | 7.3 | 3.8 |
| Narragansett | | | |
| Sand Hill Cove | 10.5 | 5.7 | 4.8 |
| Galilee and Jerusalem, Point Judith Pond | 9.5 | 5.7 | 3.8 |

TABLE 1-10

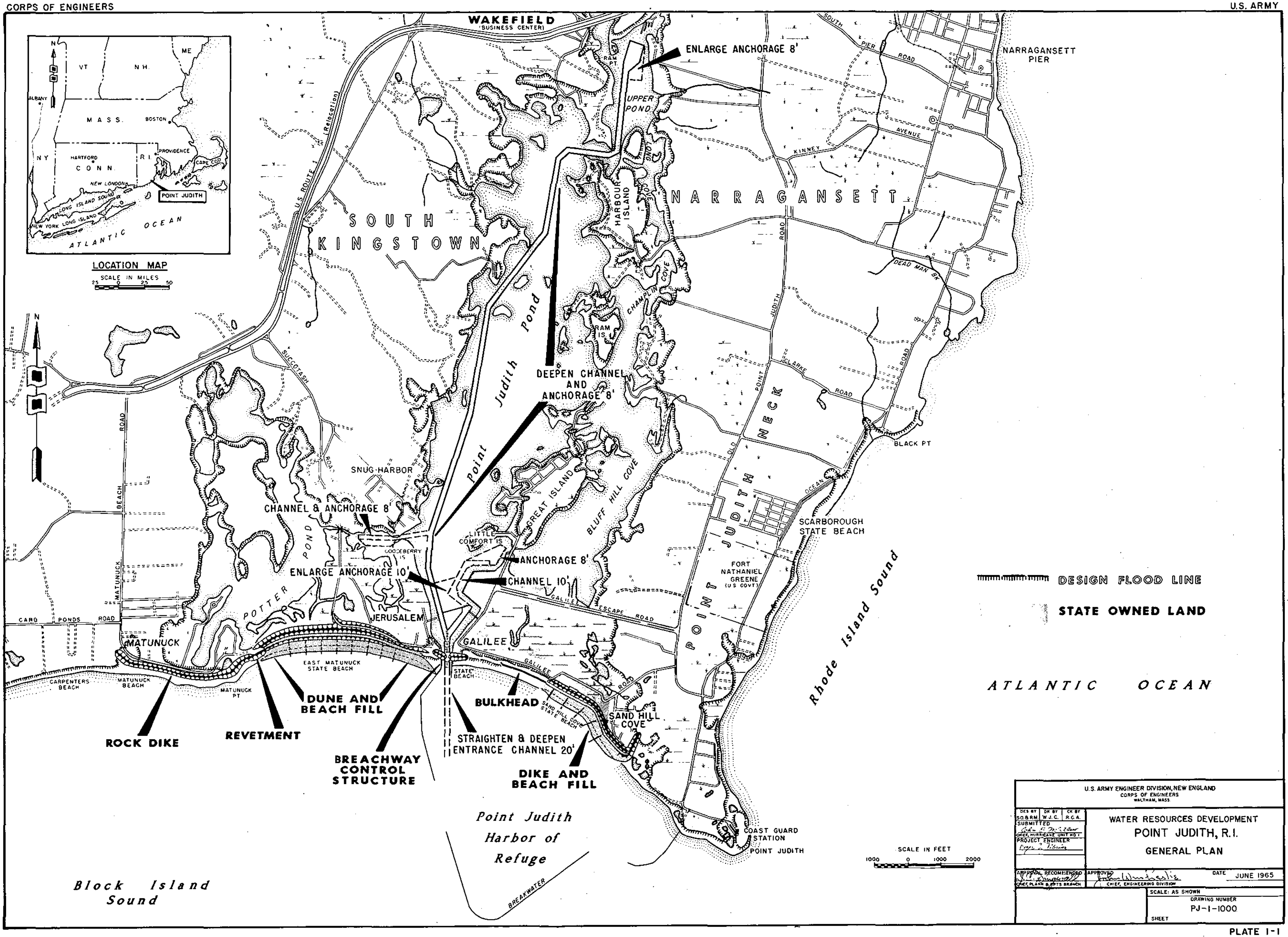
EFFECT OF WATER RESOURCES DEVELOPMENT PROJECT ON
HURRICANE FLOOD LEVELS - POINT JUDITH AREA
HURRICANE CAROL, 31 AUGUST 1954

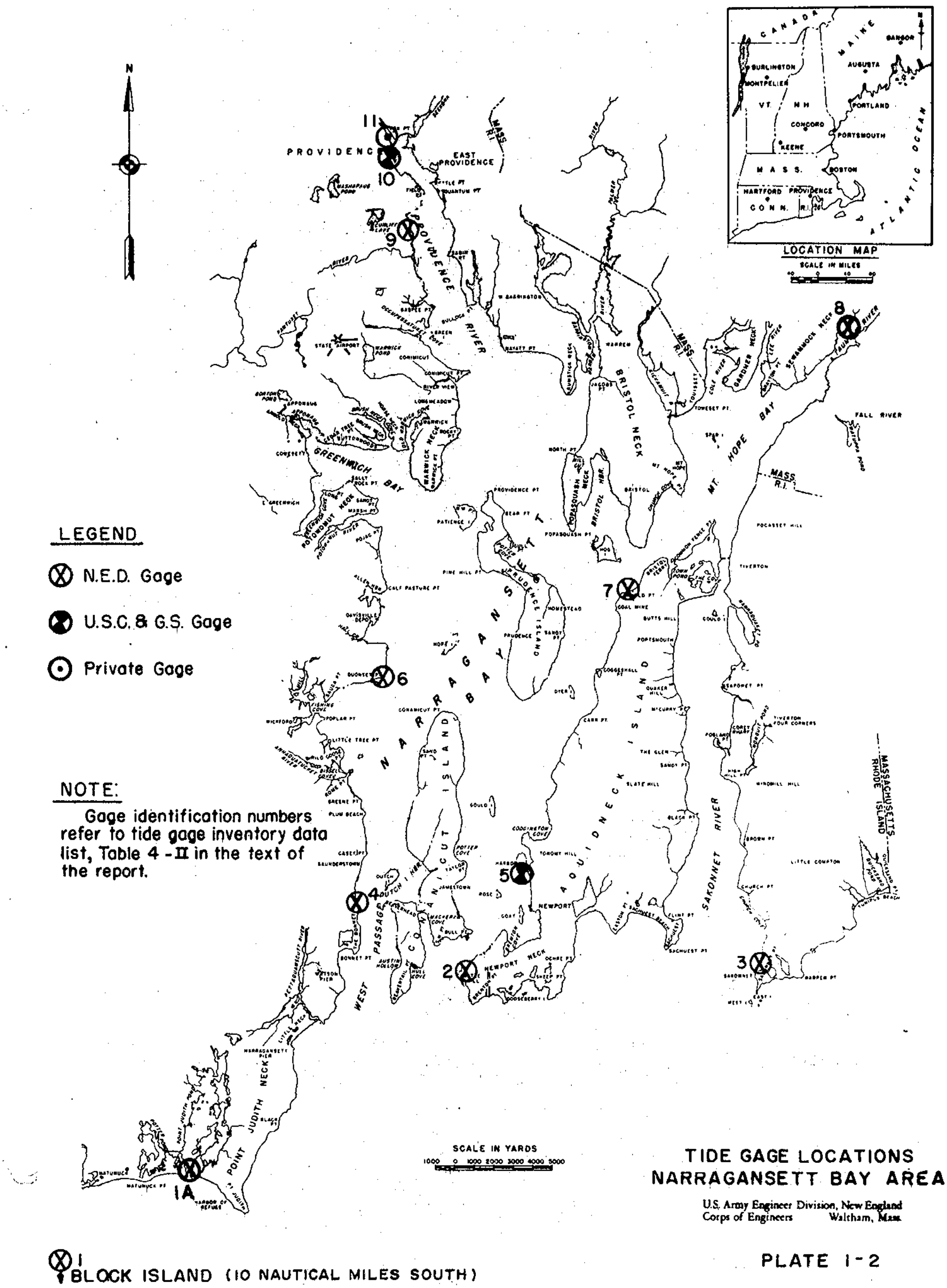
| Locality | Flood Levels Without Barriers (feet,msl) | Flood Levels With Barriers (feet,msl) | Reduction (feet) |
|---|---|---|---|
| **South Kingstown** | | | |
| Matunuck | 11.9 | 6.9 | 5.0 |
| Potter Pond | 11.4 | 6.9 | 4.5 |
| Snug Harbor | 9.4 | 6.9 | 2.5 |
| North End, Point Judith Pond | 10.9 | 8.4 | 2.5 |
| Pt. Judith Upper Pond | 10.7 | 8.2 | 2.5 |
| **Narragansett** | | | |
| Sand Hill Cove | 10.1 | 6.6 | 3.5 |
| Galilee and Jerusalem, Point Judith Pond | 9.1 | 6.6 | 2.5 |

## MODIFIED VELOCITIES IN NAVIGATION OPENING

### 23. NORMAL TIDES AND CURRENTS

To determine the effect of the Breachway control structure on currents and tidal levels during normal tides, a mean tide with a range of 3.1 feet was routed through the opening. The change in tidal range in Point Judith Pond was negligible. The maximum average current through the Breachway increased from 2.9 to 3.4 knots in the immediate vicinity of the restriction. It would be dissipated rapidly a short distance away from the opening.


WAKEFIELD (BUSINESS CENTER)
ENLARGE ANCHORAGE 8'
NARRAGANSETT PIER
UPPER POND
SOUTH KINGSTOWN
NARRAGANSETT
HARBOUR ISLAND
RAM IS
Point Judith Pond
CHAMPLIN COVE
DEEPEN CHANNEL AND ANCHORAGE 8'
SNUG HARBOR
CHANNEL & ANCHORAGE 8'
GREAT ISLAND
BLUFF HILL COVE
LITTLE COMFORT IS
GOOSEBERRY IS
ANCHORAGE 8'
ENLARGE ANCHORAGE 10'
CHANNEL 10'
POTTER POND
JERUSALEM
GALILEE
MATUNUCK
CARPENTERS BEACH
MATUNUCK BEACH
MATUNUCK PT
EAST MATUNUCK STATE BEACH
STATE BEACH
SAND HILL COVE STATE BEACH
SAND HILL COVE
DUNE AND BEACH FILL
BULKHEAD
ROCK DIKE
REVETMENT
BREACHWAY CONTROL STRUCTURE
STRAIGHTEN & DEEPEN ENTRANCE CHANNEL 20'
DIKE AND BEACH FILL
Point Judith Harbor of Refuge
BREAKWATER
Block Island Sound
Rhode Island Sound
ATLANTIC OCEAN
POINT JUDITH NECK
SCARBOROUGH STATE BEACH
FORT NATHANIEL GREENE (U S GOVT)
BLACK PT
COAST GUARD STATION
POINT JUDITH
U.S. ROUTE 1 (Relocation)
SUCCOTASH ROAD
MATUNUCK BEACH ROAD
CARD PONDS ROAD
GALILEE ESCAPE ROAD
OLD POINT JUDITH ROAD
CLARKE ROAD
OCEAN ROAD
DEAD MAN RD
KINNEY AVENUE
SOUTH PIER ROAD
DESIGN FLOOD LINE
STATE OWNED LAND
LOCATION MAP
SCALE IN MILES
25 0 25 50
ME
VT
N.H.
MASS.
BOSTON
ALBANY
N.Y.
HARTFORD
CONN.
R.I.
PROVIDENCE
NEW LONDON
CAPE COD
LONG ISLAND SOUND
LONG ISLAND
NEW YORK
POINT JUDITH
ATLANTIC OCEAN
SCALE IN FEET
1000 0 1000 2000
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
GENERAL PLAN
DATE JUNE 1965
SCALE: AS SHOWN
DRAWING NUMBER
PJ-1-1000




TIDE GAGE LOCATIONS
NARRAGANSETT BAY AREA

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

PLATE 1-2

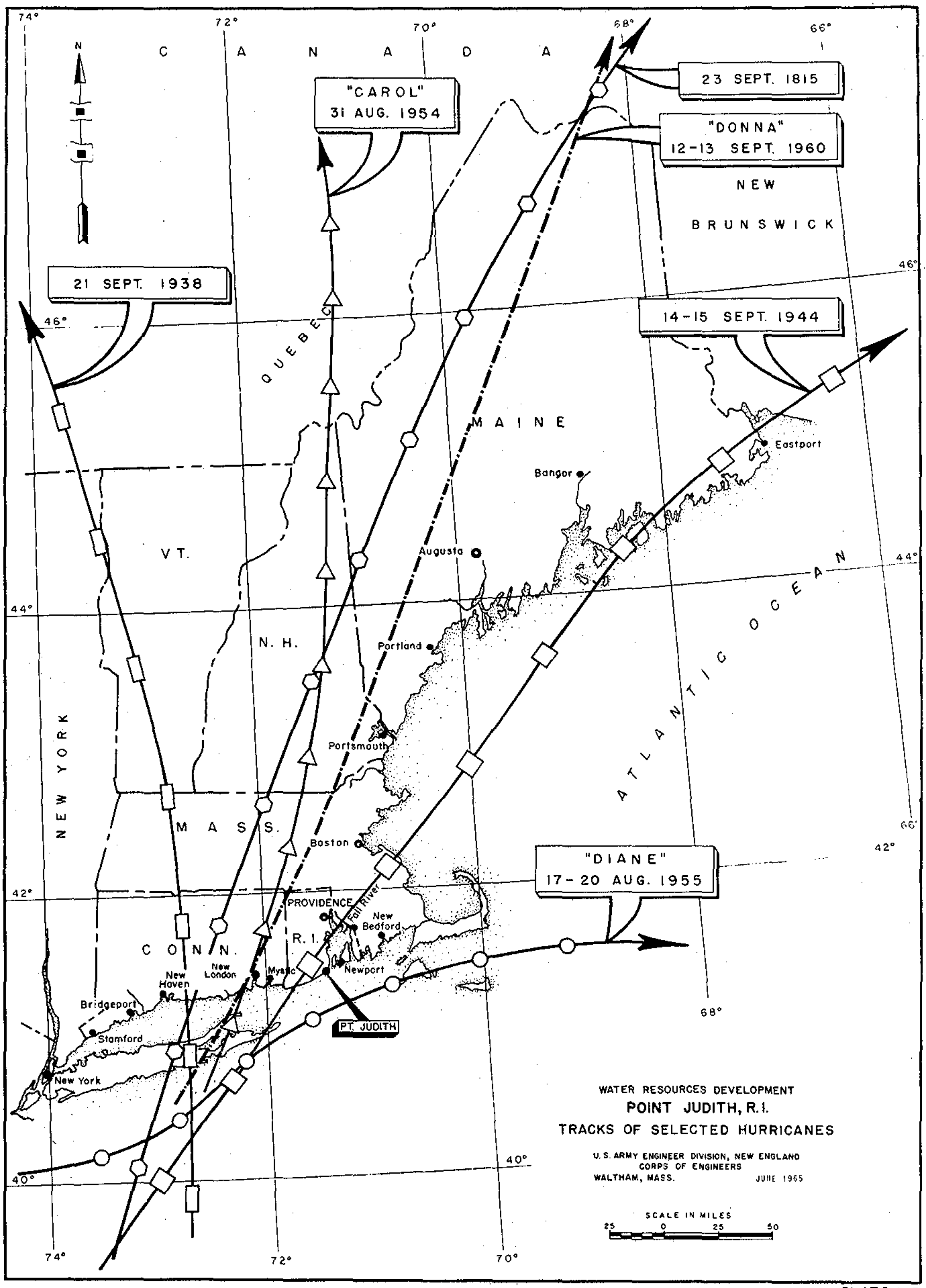
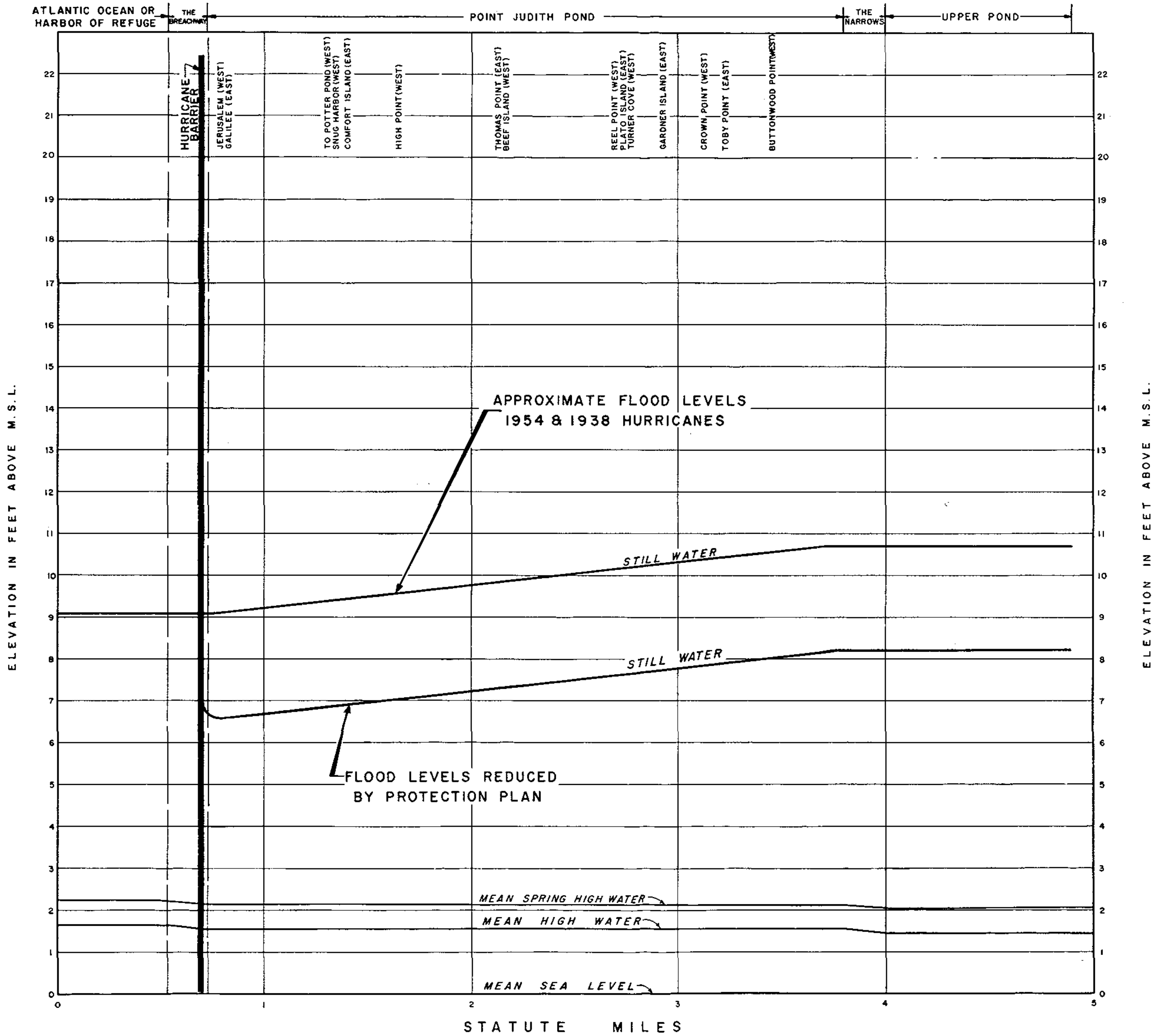

CANADA
QUEBEC
NEW BRUNSWICK
MAINE
VT.
N. H.
NEW YORK
MASS.
CONN.
R. I.
ATLANTIC OCEAN
"CAROL" 31 AUG. 1954
23 SEPT. 1815
"DONNA" 12-13 SEPT. 1960
21 SEPT. 1938
14-15 SEPT. 1944
"DIANE" 17-20 AUG. 1955
Eastport
Bangor
Augusta
Portland
Portsmouth
Boston
PROVIDENCE
Fall River
New Bedford
Newport
Mystic
New London
New Haven
Bridgeport
Stamford
New York
PT. JUDITH
74°
72°
70°
68°
66°
46°
44°
42°
40°
N
WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
TRACKS OF SELECTED HURRICANES
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
JUNE 1965
SCALE IN MILES
25 0 25 50

PLATE I-3




NOTE:
*WATER LEVELS SHOWN ARE FOR THE 1954 HURRICANE TIDE (EL. 9.1) WHICH HAD A WIDER TIME BASE AND HENCE IS MORE CRITICAL THAN THE 1938 HURRICANE TIDE (EL. 9.5).*

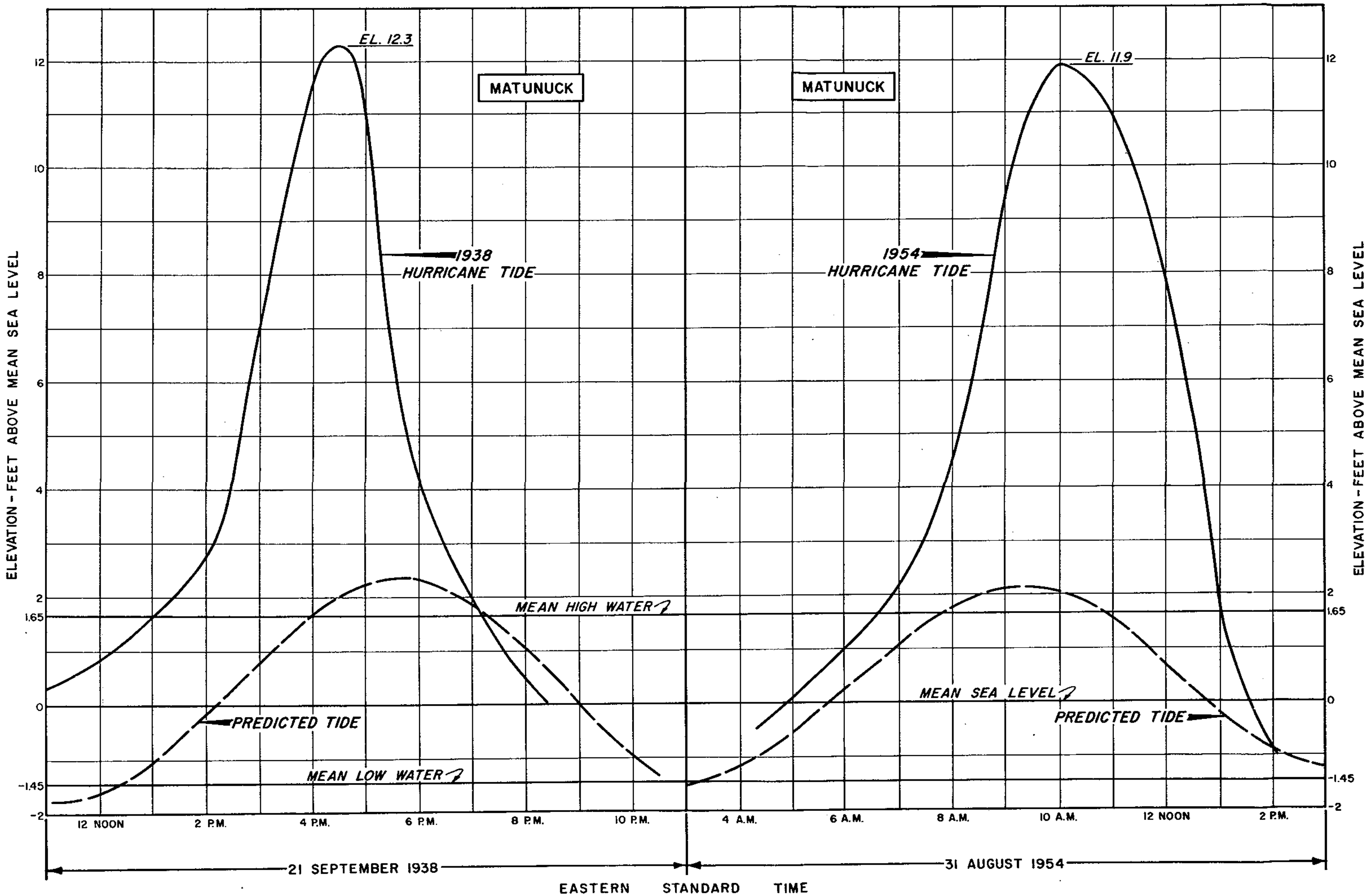
WATER RESOURCES DEVELOPMENT

POINT JUDITH, R.I.

EFFECT OF HURRICANE PROTECTION PLAN IN REDUCING FLOOD LEVELS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

SCALE AS SHOWN



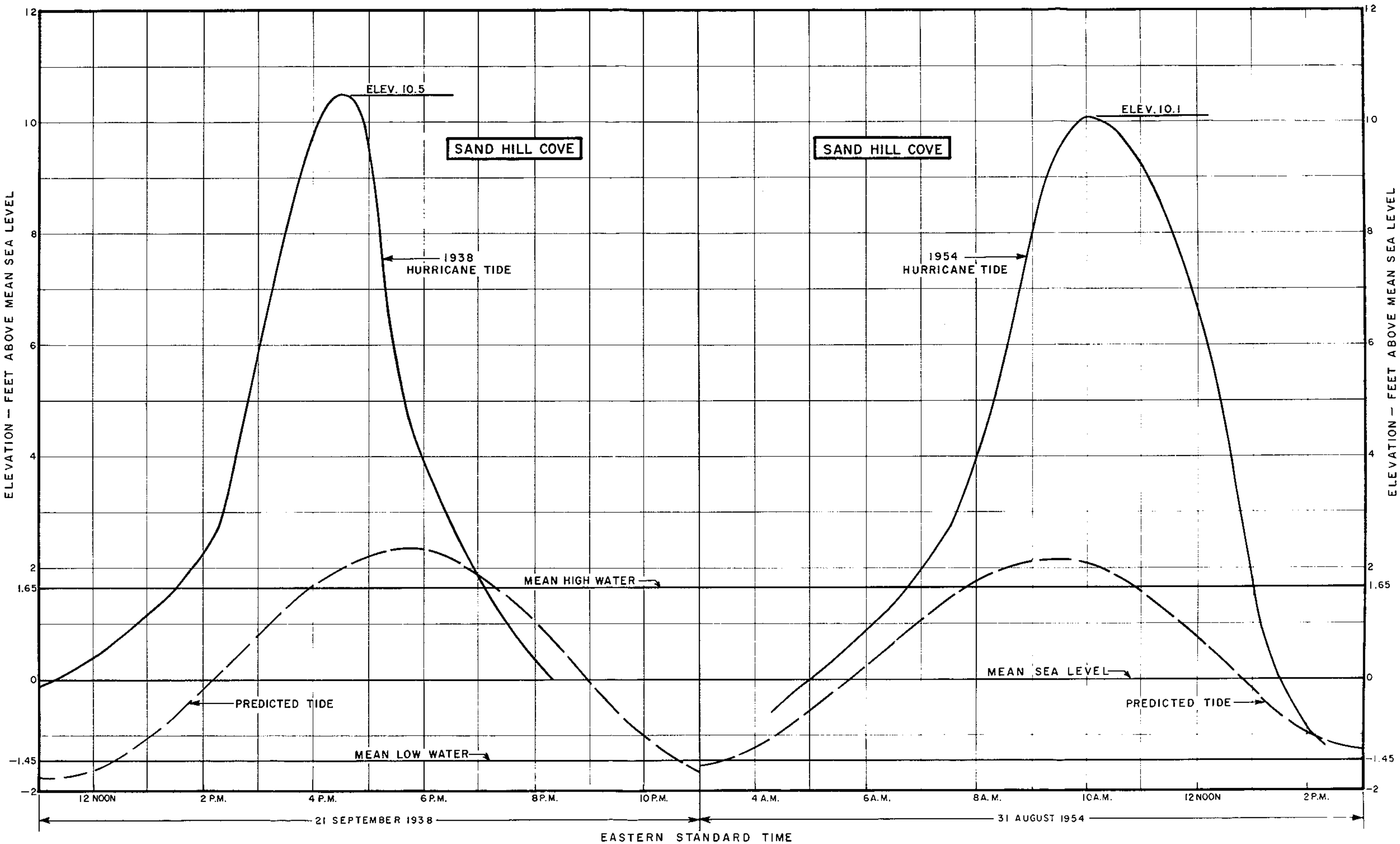

**NOTE:**
*Hurricane of September 21, 1938, tide curve based on high water marks at Matunuck and hurricane tide at Newport, Rhode Island, stage related to Matunuck.*

**NOTE:**
*Hurricane Carol, August 31, 1954, tide curve based on high water marks at Matunuck and hurricane tide at Newport, Rhode Island, stage related to Matunuck.*

WATER RESOURCES DEVELOPMENT -
POINT JUDITH, R.I.
TIDE CURVES
HURRICANES OF 1938 & 1954

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

SHEET 1 OF 3



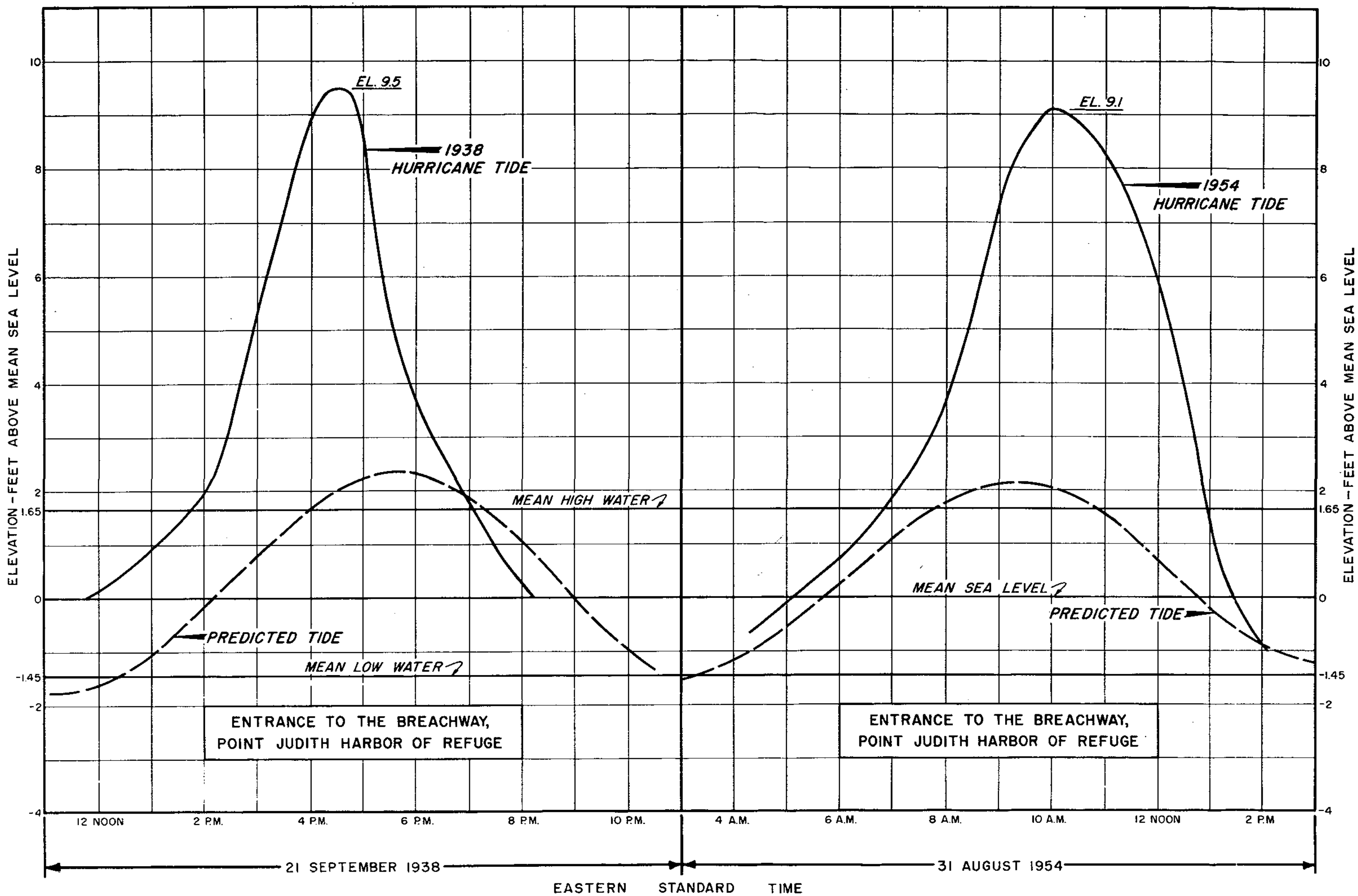

NOTE:
*Hurricane of September 21, 1938 tide curve based on high water marks at Sand Hill Cove and hurricane tide at Newport, Rhode Island, stage related to Sand Hill Cove.*

NOTE:
*Hurricane Carol August 31, 1954 tide curve based on high water marks at Sand Hill Cove and hurricane tide at Newport, Rhode Island, stage related to Sand Hill Cove.*

WATER RESOURCES DEVELOPMENT
POINT JUDITH, R. I.
TIDE CURVES
HURRICANES OF 1938 & 1954

SHEET 2 OF 3

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.




NOTE:

*Hurricane of September 21, 1938 tide curve based on high water marks at Point Judith Harbor of Refuge area and hurricane tide at Newport, Rhode Island, stage related to entrance to The Breachway, Point Judith Harbor of Refuge.*

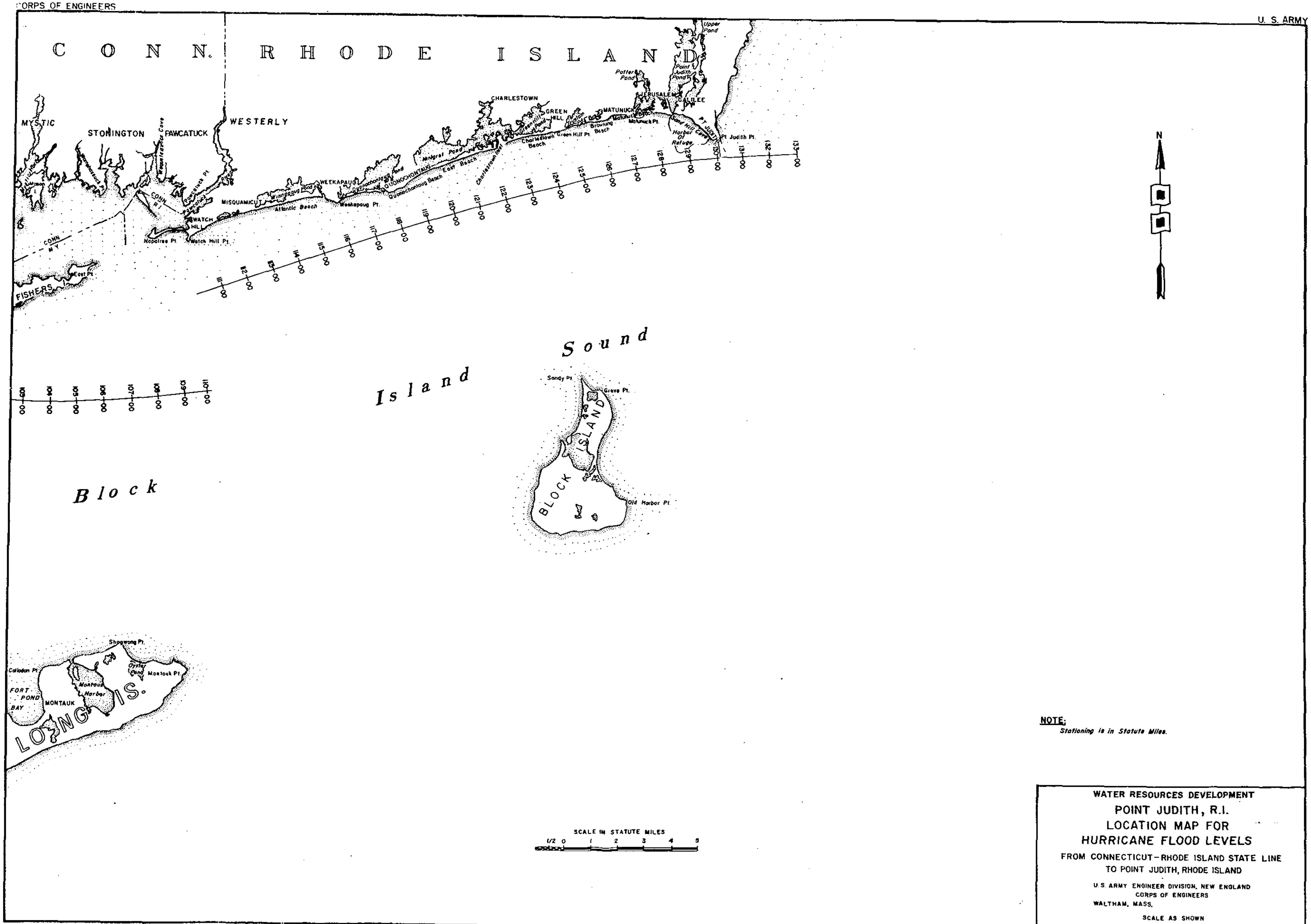
NOTE:

*Hurricane Carol, August 31, 1954 tide curve based on high water marks at Point Judith Harbor of Refuge area and hurricane tide at Newport, Rhode Island, stage related to entrance to The Breachway, Point Judith Harbor of Refuge.*

WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
TIDE CURVES
HURRICANES OF 1938 & 1954

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

SHEET 3 OF 3




NOTE:
*Stationing is in Statute Miles.*

**WATER RESOURCES DEVELOPMENT**

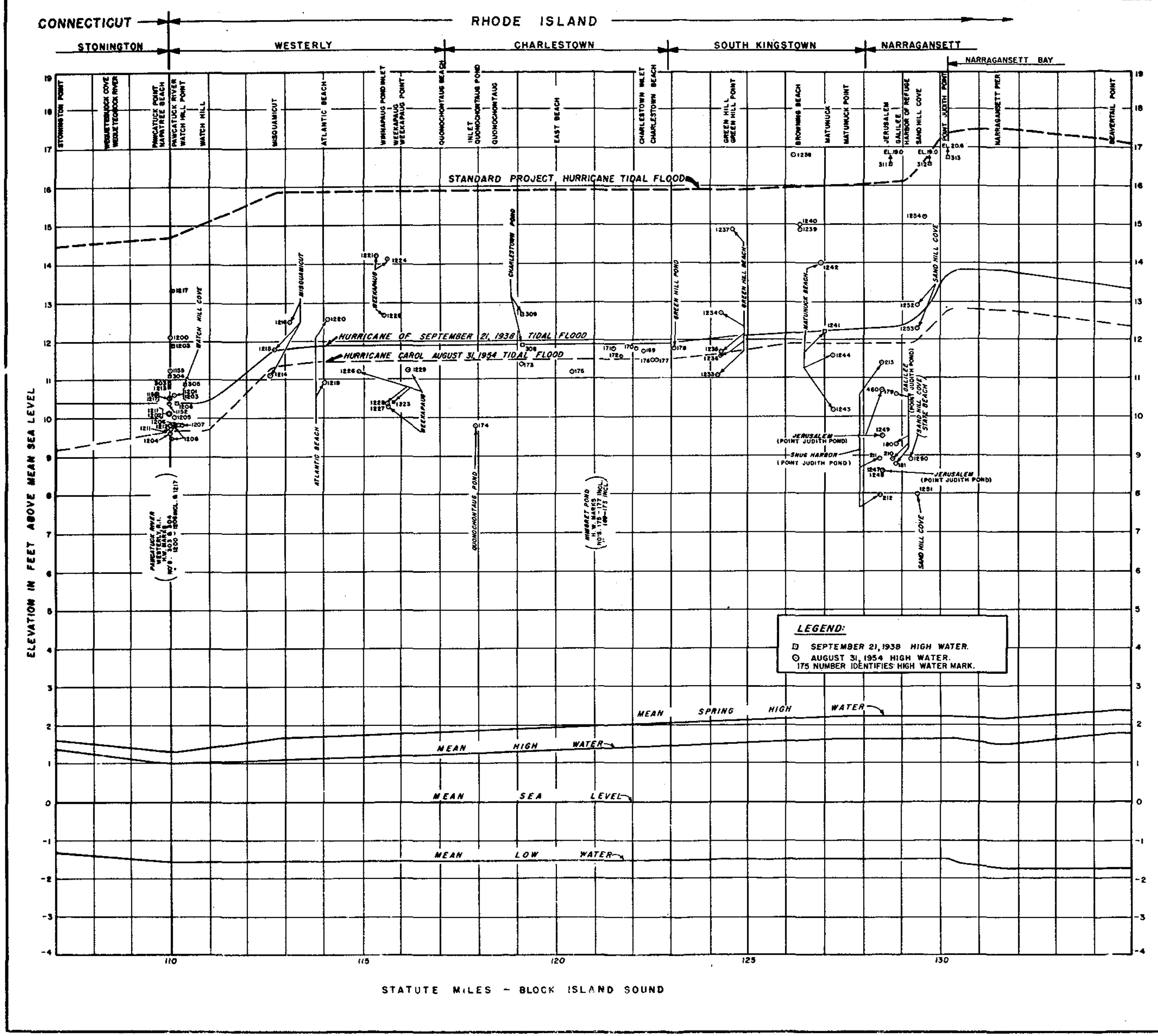
**POINT JUDITH, R.I.**

**LOCATION MAP FOR HURRICANE FLOOD LEVELS**

FROM CONNECTICUT–RHODE ISLAND STATE LINE TO POINT JUDITH, RHODE ISLAND

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

SCALE AS SHOWN



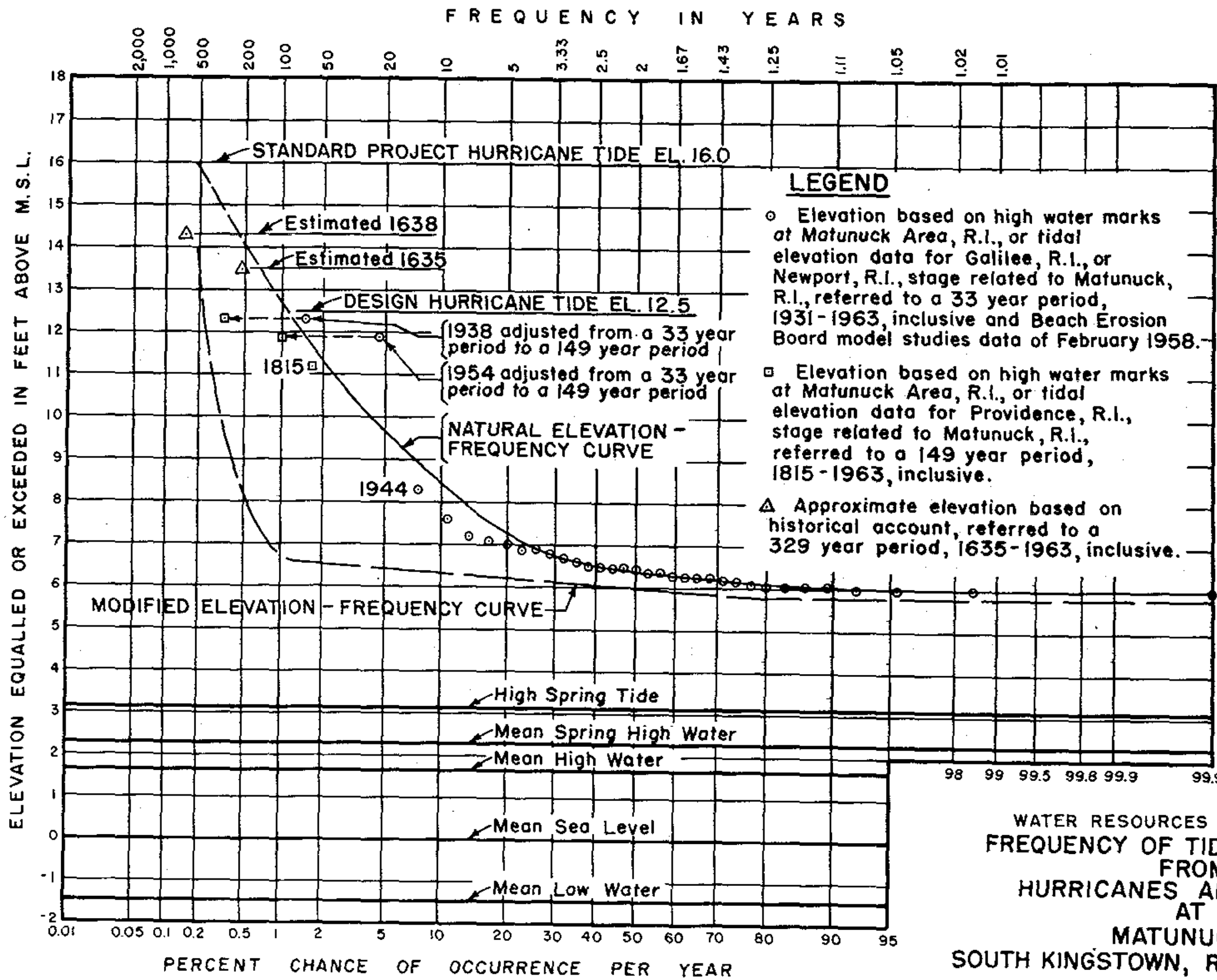

WATER RESOURCES DEVELOPMENT

POINT JUDITH, R.I.

**HURRICANE FLOOD LEVELS**

FROM CONNECTICUT-RHODE ISLAND STATE LINE TO POINT JUDITH, RHODE ISLAND

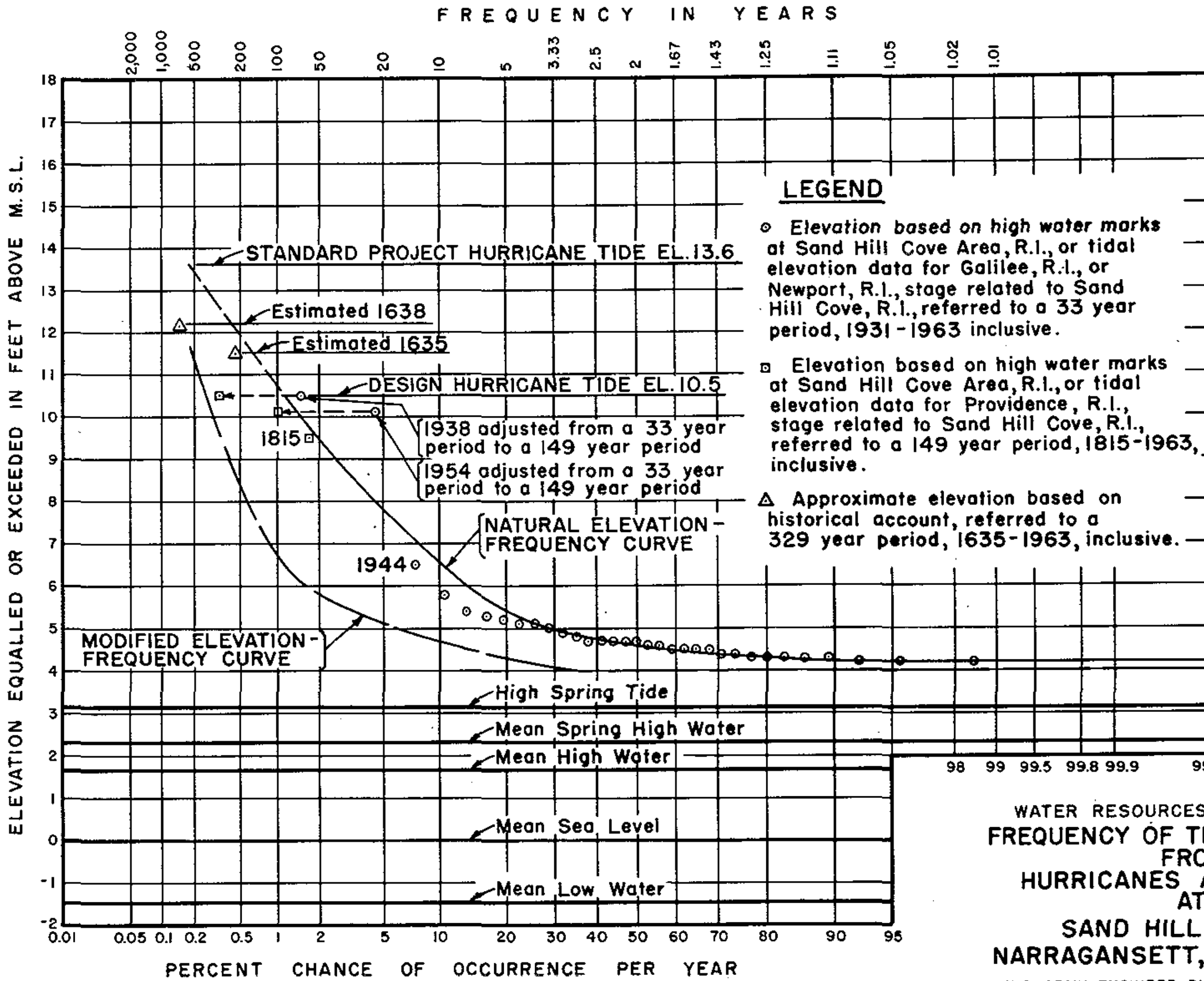
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
SCALE AS SHOWN




WATER RESOURCES DEVELOPMENT

**FREQUENCY OF TIDAL FLOODING FROM HURRICANES AND STORMS AT MATUNUCK SOUTH KINGSTOWN, RHODE ISLAND**

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1965

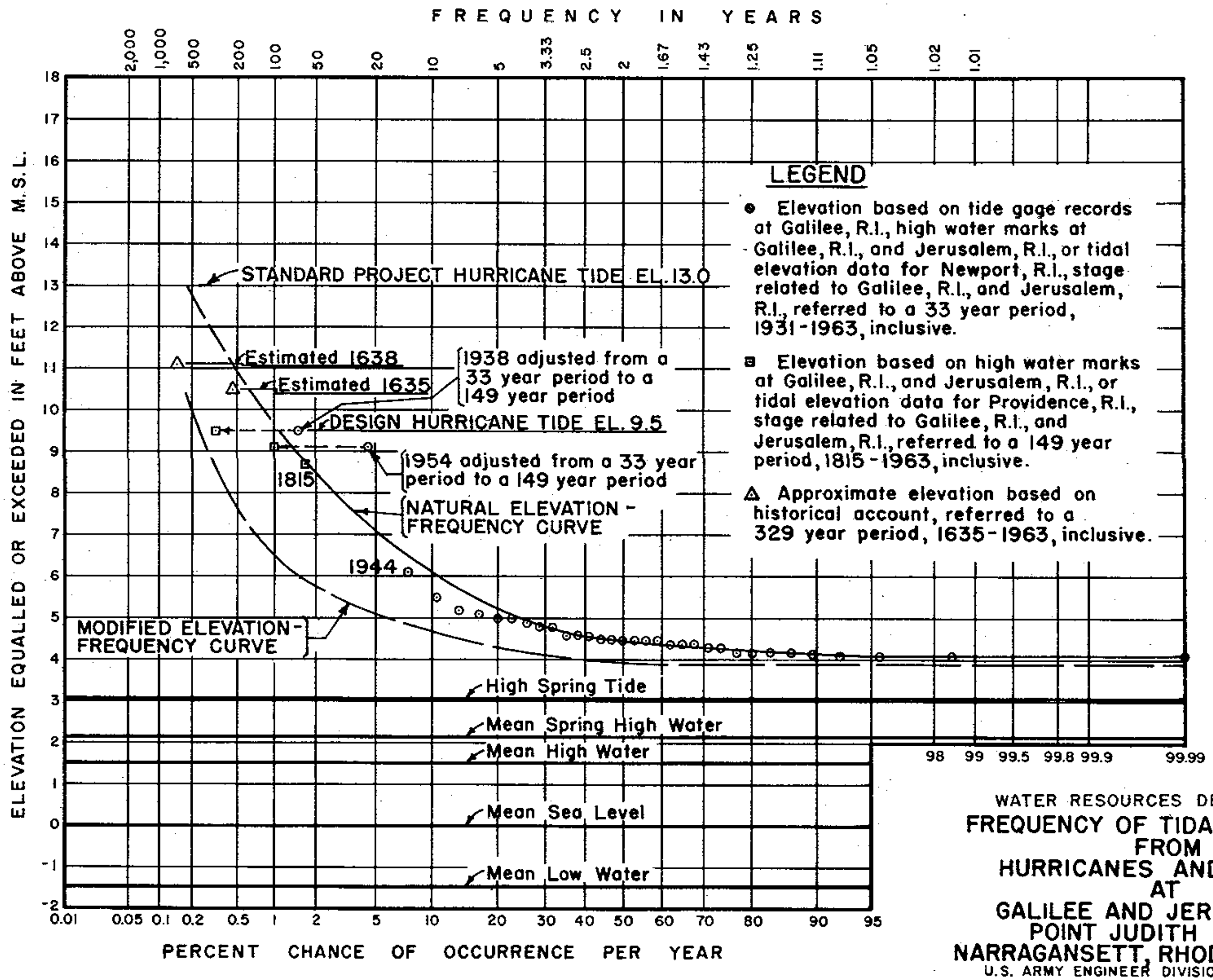



WATER RESOURCES DEVELOPMENT

**FREQUENCY OF TIDAL FLOODING FROM HURRICANES AND STORMS AT SAND HILL COVE NARRAGANSETT, RHODE ISLAND**

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1965

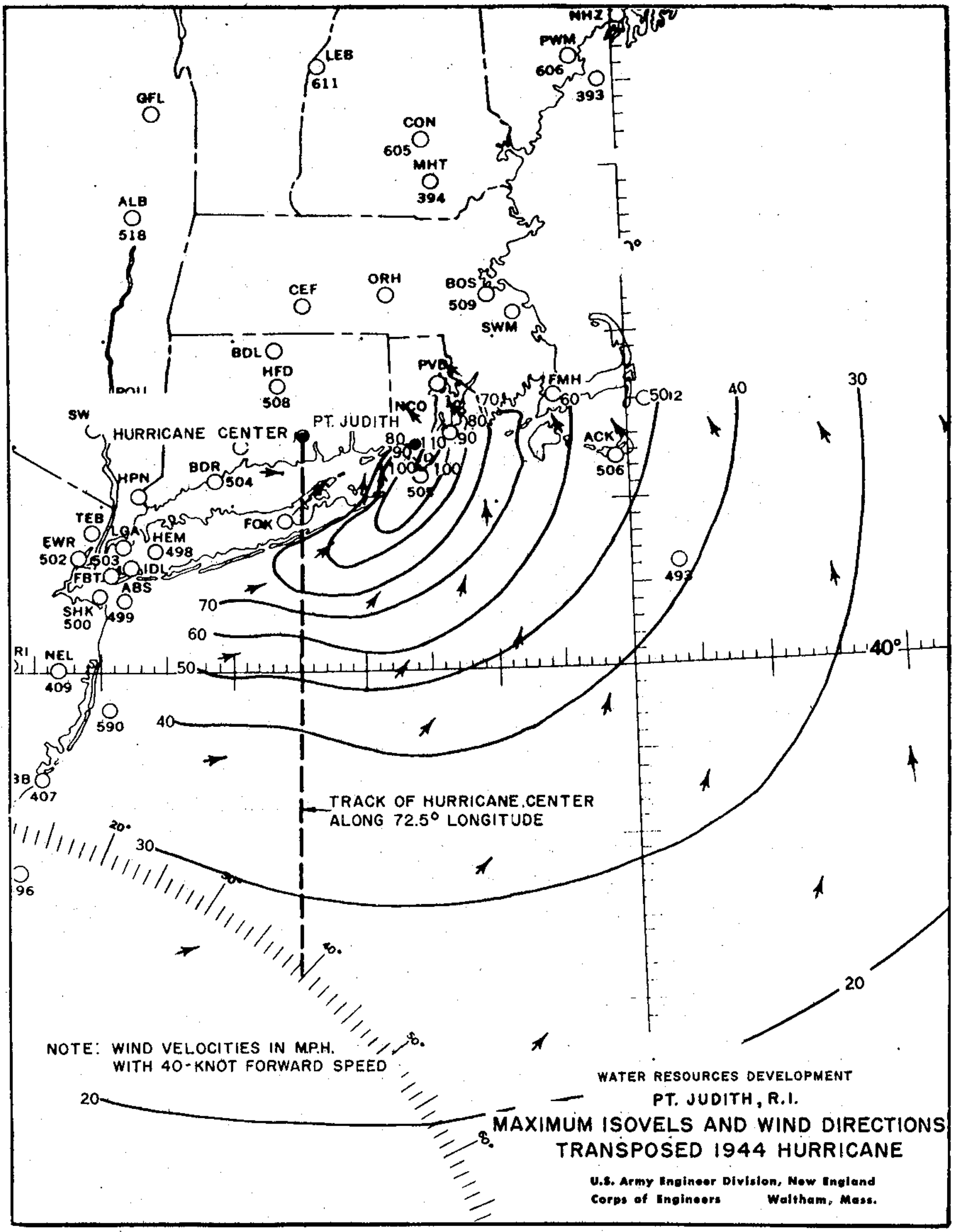
**PLATE I-11**




WATER RESOURCES DEVELOPMENT

**FREQUENCY OF TIDAL FLOODING FROM HURRICANES AND STORMS AT GALILEE AND JERUSALEM POINT JUDITH POND NARRAGANSETT, RHODE ISLAND**

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1965




WATER RESOURCES DEVELOPMENT

PT. JUDITH, R.I.

**MAXIMUM ISOVELS AND WIND DIRECTIONS TRANSPOSED 1944 HURRICANE**

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

U.S. WEATHER BUREAU DATA

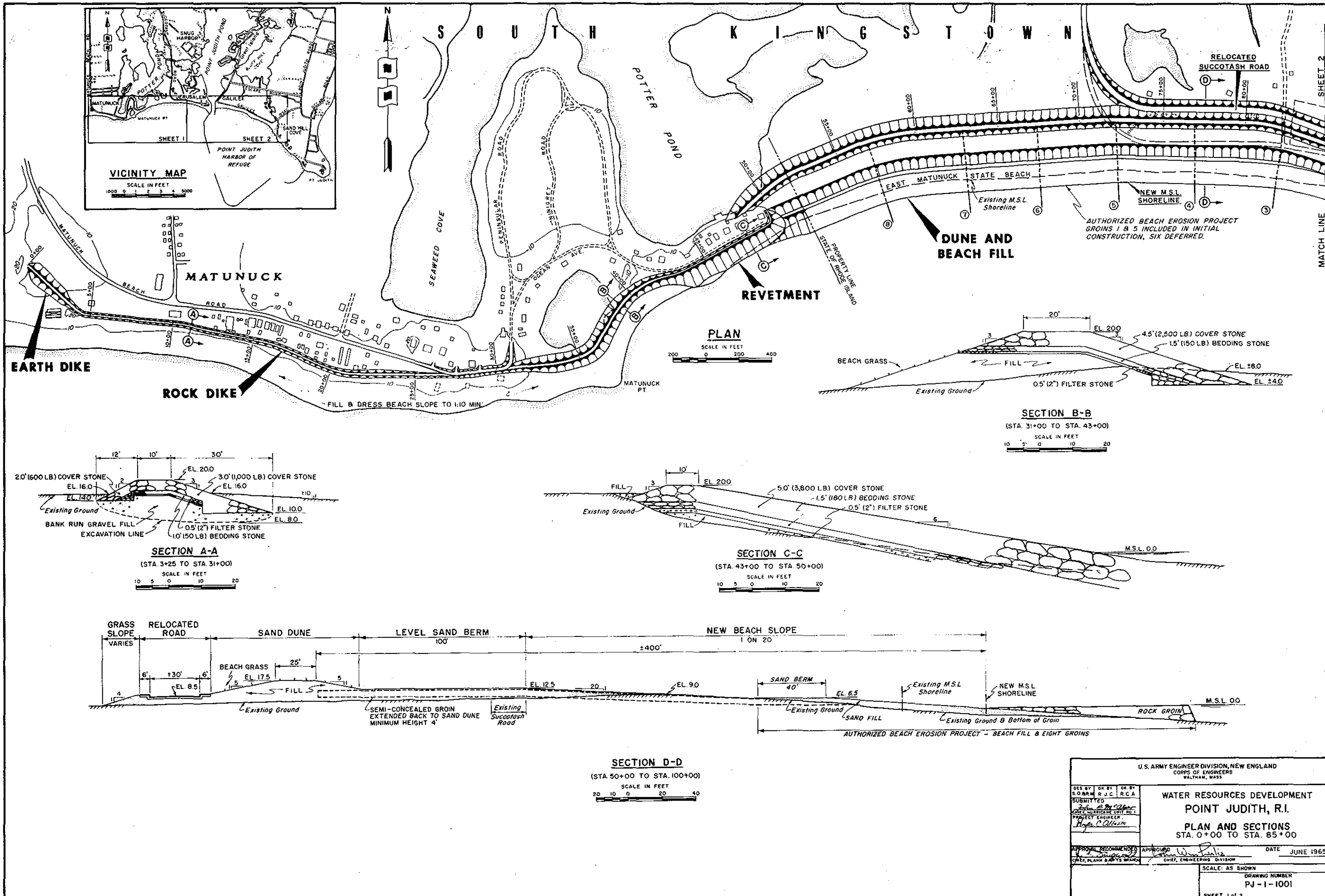

SOUTH KINGSTOWN
VICINITY MAP
SCALE IN FEET
POTTER POND
SEAWEED COVE
MATUNUCK
EARTH DIKE
ROCK DIKE
REVETMENT
DUNE AND BEACH FILL
EAST MATUNUCK STATE BEACH
PROPERTY LINE STATE OF RHODE ISLAND
NEW M.S.L. SHORELINE
Existing M.S.L. Shoreline
AUTHORIZED BEACH EROSION PROJECT GROINS 1 & 5 INCLUDED IN INITIAL CONSTRUCTION, SIX DEFERRED.
RELOCATED SUCCOTASH ROAD
MATCH LINE
SHEET 2
FILL & DRESS BEACH SLOPE TO 1:10 MIN.
MATUNUCK PT.
PLAN
SECTION A-A
(STA. 3+25 TO STA. 31+00)
2.0' (600 LB.) COVER STONE
3.0' (1,000 LB.) COVER STONE
0.5' (2") FILTER STONE
1.0' (50 LB.) BEDDING STONE
BANK RUN GRAVEL FILL
EXCAVATION LINE
Existing Ground
SECTION B-B
(STA. 31+00 TO STA. 43+00)
4.5' (2,500 LB.) COVER STONE
1.5' (150 LB.) BEDDING STONE
0.5' (2") FILTER STONE
BEACH GRASS
SECTION C-C
(STA. 43+00 TO STA. 50+00)
5.0' (3,800 LB.) COVER STONE
1.5' (180 LB.) BEDDING STONE
0.5' (2") FILTER STONE
SECTION D-D
(STA. 50+00 TO STA. 100+00)
GRASS SLOPE
RELOCATED ROAD
SAND DUNE
LEVEL SAND BERM
NEW BEACH SLOPE 1 ON 20
SEMI-CONCEALED GROIN EXTENDED BACK TO SAND DUNE MINIMUM HEIGHT 4'
Existing Succotash Road
SAND BERM
SAND FILL
ROCK GROIN
AUTHORIZED BEACH EROSION PROJECT - BEACH FILL & EIGHT GROINS
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
PLAN AND SECTIONS
STA. 0+00 TO STA. 85+00
DATE JUNE 1965
SCALE: AS SHOWN
DRAWING NUMBER PJ-1-1001
SHEET 1 of 2

PLATE I-14

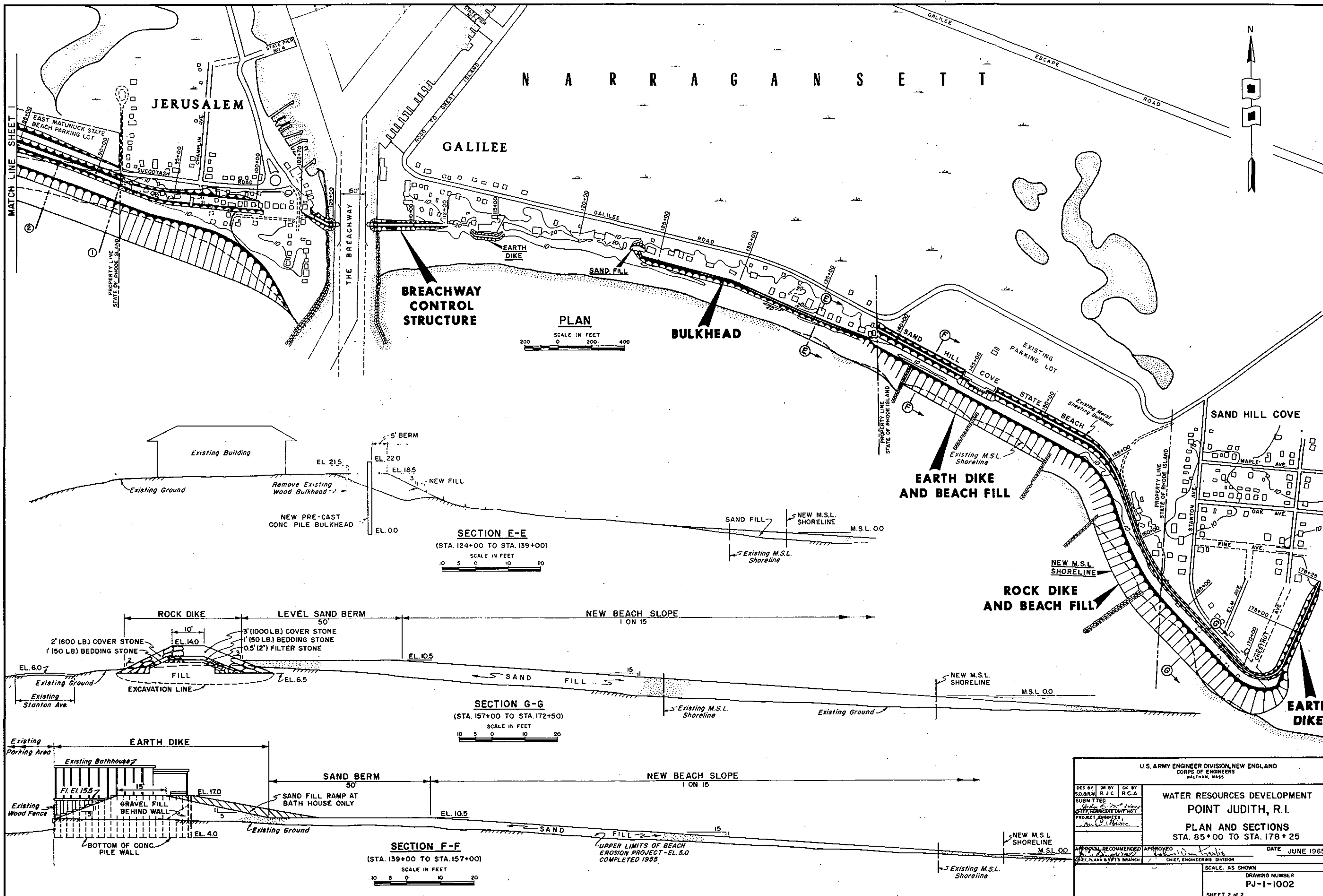
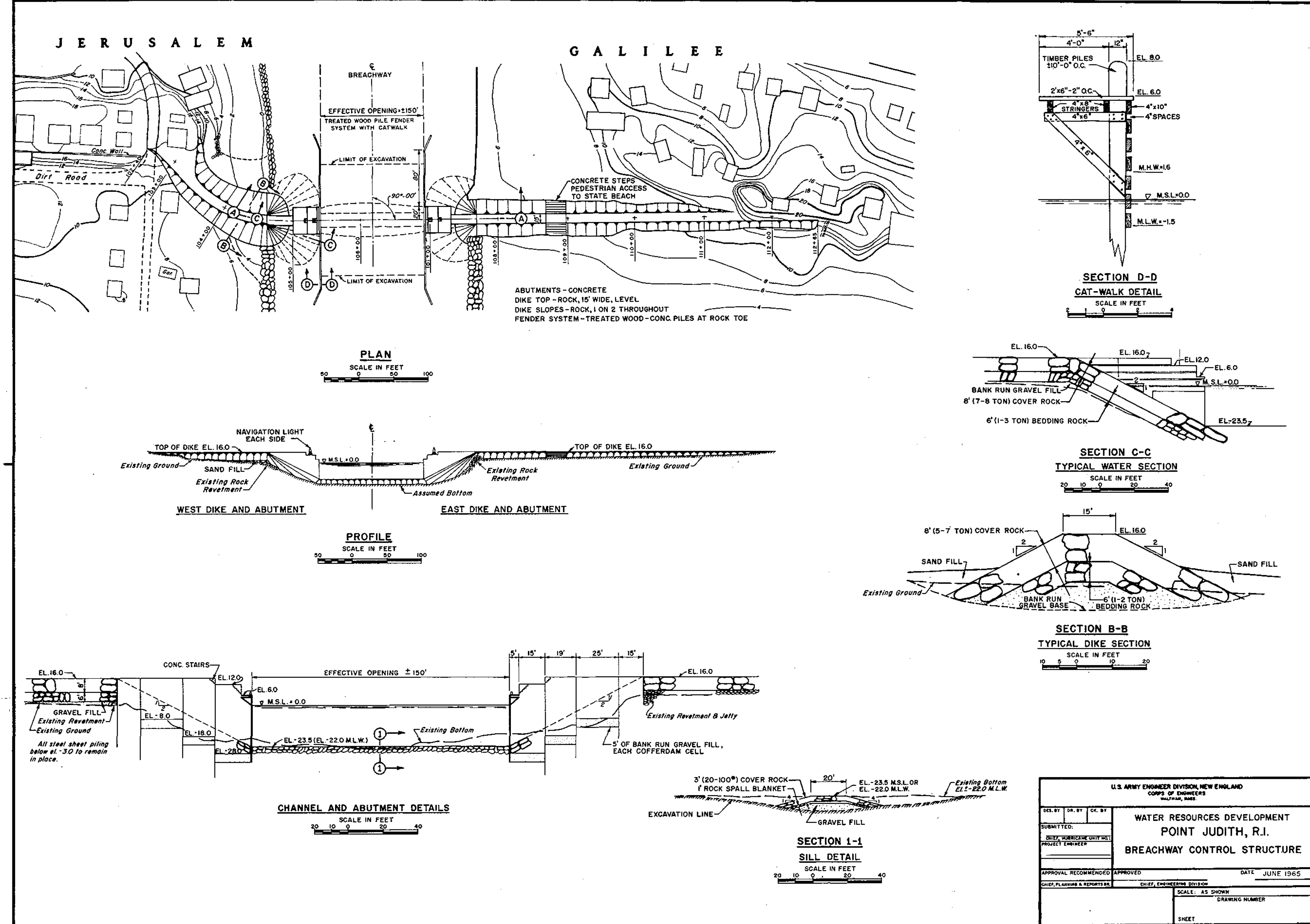

NARRAGANSETT
JERUSALEM
GALILEE
EAST MATUNUCK STATE BEACH PARKING LOT
MATCH LINE SHEET 1
SUCCOTASH ROAD
CHAMPLIN AVE.
STATE PIER NO. 4
STATE PIER NO. 3
ROAD TO GREAT ISLAND
GALILEE ESCAPE ROAD
THE BREACHWAY
150'
PROPERTY LINE STATE OF RHODE ISLAND
BREACHWAY CONTROL STRUCTURE
EARTH DIKE
SAND FILL
BULKHEAD
GALILEE ROAD
PLAN
SCALE IN FEET
200 0 200 400
SAND HILL COVE STATE BEACH
EXISTING PARKING LOT
Existing Metal Sheeting Bulkhead
Existing M.S.L. Shoreline
EARTH DIKE AND BEACH FILL
NEW M.S.L. SHORELINE
ROCK DIKE AND BEACH FILL
EARTH DIKE
SAND HILL COVE
MAPLE AVE.
OAK AVE.
PINE AVE.
STANTON AVE.
ELM AVE.
CHESTNUT AVE.
N
Existing Building
EL. 21.5
5' BERM
EL. 22.0
EL. 18.5
NEW FILL
Existing Ground
Remove Existing Wood Bulkhead
NEW PRE-CAST CONC. PILE BULKHEAD
EL. 0.0
SAND FILL
NEW M.S.L. SHORELINE
M.S.L. 0.0
Existing M.S.L. Shoreline
SECTION E-E
(STA. 124+00 TO STA. 139+00)
SCALE IN FEET
10 5 0 10 20
ROCK DIKE
LEVEL SAND BERM
50'
NEW BEACH SLOPE
1 ON 15
10'
EL. 14.0
2' (600 LB.) COVER STONE
1' (50 LB.) BEDDING STONE
3' (1000 LB.) COVER STONE
1' (50 LB.) BEDDING STONE
0.5' (2") FILTER STONE
EL. 10.5
EL. 6.0
Existing Ground
FILL
EXCAVATION LINE
EL. 6.5
SAND FILL
Existing Stanton Ave.
NEW M.S.L. SHORELINE
M.S.L. 0.0
Existing M.S.L. Shoreline
Existing Ground
SECTION G-G
(STA. 157+00 TO STA. 172+50)
SCALE IN FEET
10 5 0 10 20
Existing Parking Area
EARTH DIKE
Existing Bathhouse
Fl. El. 15.5
15'
EL. 17.0
GRAVEL FILL BEHIND WALL
Existing Wood Fence
EL. 4.0
BOTTOM OF CONC. PILE WALL
SAND BERM
50'
SAND FILL RAMP AT BATH HOUSE ONLY
Existing Ground
EL. 10.5
NEW BEACH SLOPE
1 ON 15
SAND FILL
UPPER LIMITS OF BEACH EROSION PROJECT - EL. 5.0 COMPLETED 1955
NEW M.S.L. SHORELINE
M.S.L. 0.0
Existing M.S.L. Shoreline
SECTION F-F
(STA. 139+00 TO STA. 157+00)
SCALE IN FEET
10 5 0 10 20
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
PLAN AND SECTIONS
STA. 85+00 TO STA. 178+25
DES BY S.O.B.R.M. DR BY R.J.C. CK BY R.C.A.
SUBMITTED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, PLANNING & REPORTS BRANCH
APPROVED
CHIEF, ENGINEERING DIVISION
DATE JUNE 1965
SCALE: AS SHOWN
DRAWING NUMBER
PJ-1-1002
SHEET 2 of 2

PLATE I-15




U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT
POINT JUDITH, R.I.
BREACHWAY CONTROL STRUCTURE

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, HURRICANE UNIT NO.
PROJECT ENGINEER
APPROVAL RECOMMENDED | APPROVED
CHIEF, PLANNING & REPORTS BR. | CHIEF, ENGINEERING DIVISION
DATE JUNE 1965
SCALE: AS SHOWN
DRAWING NUMBER
SHEET